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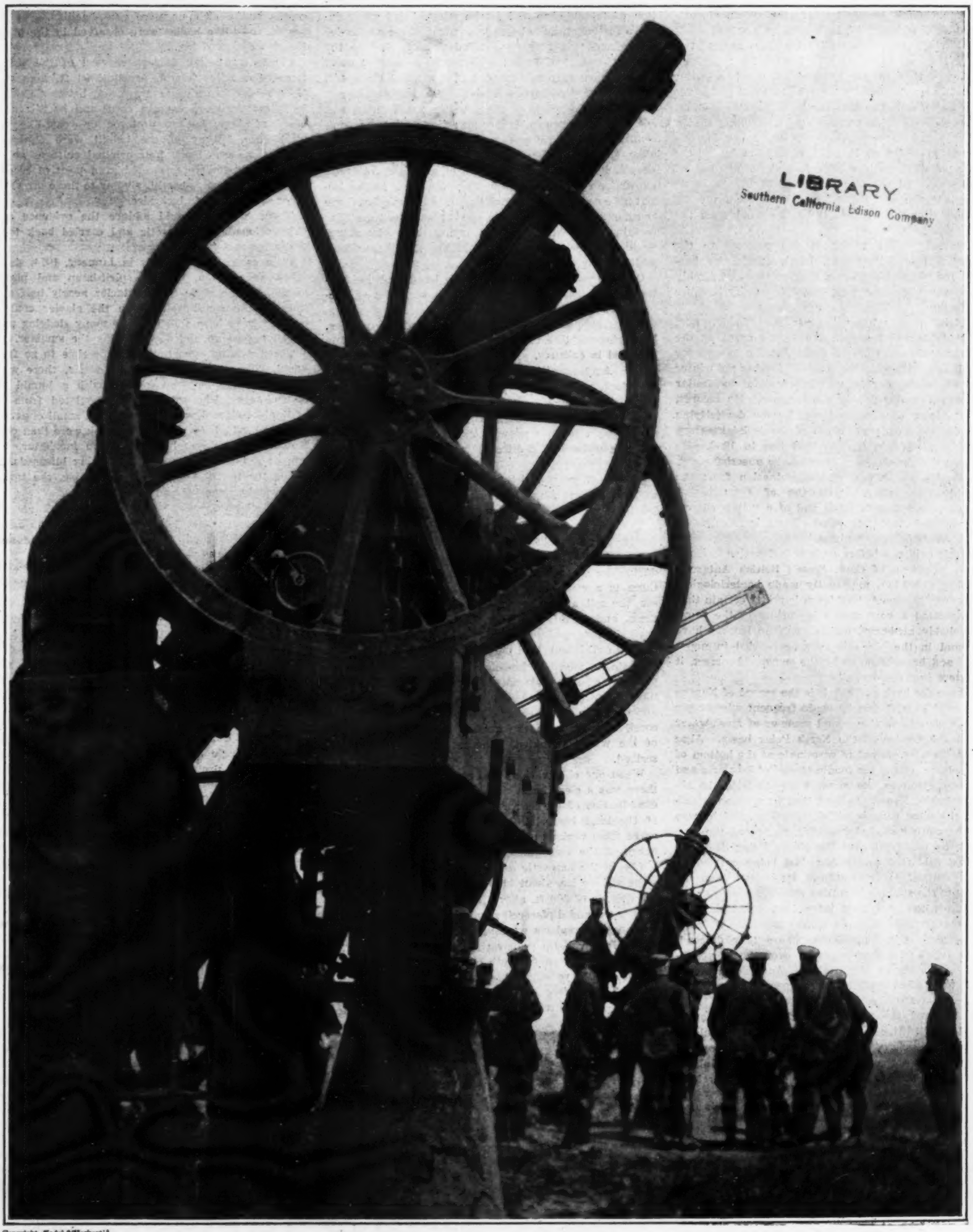


Anti-aircraft guns improvised by the Belgians

PROTECTION AGAINST AIRCRAFT [See page 244]

Bacteria in Antarctica*

Various Species Found in Snow and Ice, and Their Origin

By A. L. McLean

THE researches we were able to prosecute during Sir Douglas Mawson's Australasian Antarctic Expedition (1911-14) in the subject of bacterial flora of snow and ice have given rise to certain queries which, if accurately answered and correlated to the work of four previous observers, should go far towards an elucidation of the bacteriology of Antarctica as a whole.

Dr. Ekelöf[1], whose investigation for nearly two years of the soil of Snow Hill Island, near Graham Land, were rich in results and of great scientific value, made experimental exposures of Petri plates for possible bacteria in the air. He found positive growths on at least half of his culture media, claiming that a Petri plate had to be exposed for two hours for one bacterium to settle on it. His conclusion is, on the evidence of examinations of soil and on account of the unprecedented weather conditions of his Antarctic station, that the organisms he obtained from the air were impurities carried into it by the wind from the soil.

Dr. Gazert,[2] when frozen in the pack-ice to the north of Kaiser Wilhelm II. Land, sought for bacteria in the atmosphere by making cultures of freshly fallen snow. The cultures were found in every instance to be sterile.

Dr. Pirie,[3] during his voyage in the Weddell Sea, exposed plates and tubes in the crow's nest (at the top of the mainmast) of the *Scotia*, at the longest for twenty hours, with negative results. During the winter months at Scotia Bay he was unsuccessful in similar experiments, as also during the summer. He records, too, that plates of agar and media (for denitrifying organisms) were exposed on top of the deck-laboratory during the voyage in the Weddell Sea in 1903. He considered the last-named cultures to be unsatisfactory, owing to the possibility of contamination from the ship and from spray. "Growths of (apparently) *Staphylococcus pyogenes albus* and of a yellow coccus, possibly *Staphylococcus pyogenes citreus*, were obtained, and also denitrifying organisms."

With this evidence before us it is instructive to learn that Dr. Atkinson, of Capt. Scott's British Antarctic Expedition (1910-13), apparently made bacteriological examinations of snow.[4] "Atkinson is pretty certain that he has isolated a very motile bacterium in the snow. It is probably air-borne, and, though no bateria have been found in the air, this may be carried in upper currents and brought down by the snow. If correct, it is an interesting discovery."

Lastly, so far back as 1893, it is the record of Nansen in "Farthest North" that he made frequent microscopic examinations during the second summer of fresh-water pools on the floe-ice of the North Polar basin. Algæ and diatoms were proved to germinate at the bottom of these pools, providing the food material of infusoria and flagellata. Bacteria, he says, were occasionally observed. Again, Nansen noticed that in places the surface of the snow was sprinkled with dust, and he was led, after more extended inquiries, to regard the phenomenon as universal over the North Polar Sea. He attributes this fact to floating dust being carried by lofty air-currents from southern lands and then descending to the surface in falling snow.

Doubtless, too, one may infer that equatorial air-currents at a high altitude convey myriads of dust-motes towards the South Pole, where they descend, free or clinging to snow-particles, over the great ice-capped continent of Antarctica. And as evidence towards the probable truth of this speculation we have been able to furnish some isolated observations.

The locus of the main base of the Australasian Antarctic Expedition in Adelie Land was singularly fitted for research of a general character on ice and snow, since here the great inland plateau undulates downwards in *névé-fields*, declining gradually for hundreds of miles, to fall abruptly in glacial slopes to the sea. In fact, we were on the verge of the continent, with no naked mountains or outcropping nunataks[5] encircling us to the south.

[The results which were obtained from an examination of frozen algæ and frozen seaweed led us to inquire further into the bacterial content of the glacier-ice—apparently as pure as distilled water! And so the organic content of frozen algæ makes a suitable point of departure in considerations of a general character, for in these dirty green lumps of ice are represented practically the whole of the low life which exists and actively multiplies in Antarctica: algæe, diatoms (unicellular algæ), protozoa, rotifera, and bacteria. The algæ (including the diatoms) are universally found, according to the scientific reports of other Antarctic expeditions, as marine or fresh-water types in the ice-girt zone surrounding the continent. In Adelie Land one became accustomed to note in the summer-time that certain of the thawed pools among the rocky ridges were filled with a greenish slime—the filamentous, multicellular algæ.]

On comparing results in Adelie Land and in Australia, it is evident that at least four species of bacteria exist in the frozen algæ:—

(1) Gram-positive cocci, with fine, white colonies, liquefying gelatine very slowly, were almost invariably obtained in cultures.

(2) Agram-positive, sporing bacillus spreading as an abundant, pale, wrinkled, and adherent growth on all media.

(3) Gram-positive, chained, sporing bacilli, occurring as a white, profuse growth on all media. In cover-slip preparations of the ice chained bacilli were always seen.

(4) Short gram-positive bacilli, showing on agar a milky-white growth, which afterwards became yellowish in tint.

The fact of the mere presence of bacterial life in frozen algae would not seem remarkable along the fringe of the continent, where lichens and mosses thrive during the short periods of warmer weather, and where there is a continuous accession of low life from the sea, the soil, and animals. It is only natural to expect them, and to infer, further, that they migrate for a variable distance into the all-enveloping mass of ice and snow, to all intents and purposes free from organic life.

Again, in morainic ice—macroscopically pure but for particles of soil and grit in small amount—protozoa-like organisms were present, and in several cultures appeared fine, white colonies of gram-positive, staphylococci, together with the gram-positive, sporing bacilli of the white, wrinkled, adherent growth already described.

When our observations had arrived at this juncture there was a clear indication to go further afield in the examination of the ice; at all events, to see the extent of the local bacterial flora. So specimens were procured from various points, free from obvious contamination, on the ascending glacier.

(1) In the magnetic cave, cut shaft-like through the slope of blue ice, about 1100 yards south of the Hut, at an altitude of 300 ft. above the sea, were found in cultures cocci and diplococci, slender bacilli, and a "yeast." Protozoan organisms were also seen.

(2) In cover-slip preparations 200 to 300 yards, 500 yards, and 1000 yards south of the Hut occurred cocci, motile bacilli, yeast-like bodies, and protozoa.

(3) The surface-ice at 1100 yards, altitude 300 ft., yielded in cultures cocci (staphylococci) and short stout bacilli.

(4) At one mile, altitude 600 ft. to 700 ft., in surface-ice, appeared in cultures gram-positive staphylococci and slender, gram-negative, chained bacilli. Protozoa and yeast-like bodies were demonstrated in the thawed ice-chips.

(5) In the vicinity of Aladdin's Cave, five miles south of the Hut, and at an altitude of 1500 ft., surface-ice showed the presence of protozoa and yeast-like bodies. Gram-positive cocci grew in cultures on several occasions.

Ice at a depth of 4 ft. contained, besides protozoa and yeast-like bodies, gram-positive cocci and gram-negative bacilli, all in smaller numbers than on the surface. Nothing was obtained in a few cultures.

In ice at 7 ft.—from the wall of the cave—cultures were more successful, demonstrating gram-positive cocci and gram-negative bacilli (probably cocco-bacilli). Protozoans and yeast-like bodies were also present.

(6) From the Cathedral Grotto—at eleven miles, and at an altitude of 1800 ft. above the sea—specimens of ice gave in cultures growths of a gram-positive coccus and a gram-negative cocco-bacillus. No protozoa or yeast-like bodies were observed in the preparation from thawed ice.

(7) In a position fifty miles west of the Hut and twenty-five miles inland, nearly 4000 ft, high on the plateau, surface *névé* (a transition between snow and ice) was found to contain cocci and bacilli in their usual numbers, but no protozoa or yeast-like bodies were seen. Many of the bacilli were clumped in zooglœa mases. From four original cultures and several subcultures were isolated gram-positive cocci and gram-negative cocco-bacilli, similar to those grown from other specimens of glacier-ice.

Then, too, we should adduce the evidence of the cultures made in Antarctic and carried back to Australia for examination.

On a rare calm day early in January, 1914, six agar tubes were taken, with a spirit-lamp and platinum needle, up the slope of the glacier nearly half a mile towards the south-east, where the glacier could not possibly have been soiled by the many sledging parties which passed up and down during the summer.

There was no opportunity at the time to go further afield. The sun was bright and warm, there was no wind, and the ice was covered with a humid sheen of moisture. The tubes were inoculated from loops of liquid collected with the needle in small cups where thaw-water had accumulated. They were then carried back to the ship and placed in an incubator, which ran at a temperature varying, during blizzards, from about 10° to 15° C.; as a general rule, the temperature was between 18° and 20° C.

Dr. Cleland's report shows that nine cultures of ice were received, that of these, three showed no colonies, and were discarded, and that the remaining six on agar slopes exhibited growth. From three tubes "yeasts" were isolated, two of them giving a pink growth on agar, the remaining one a creamy-yellow growth. Two cultures showed the presence of a gram-positive coccus, producing a fine growth, which died out in subsequent subcultures.

It is a curious fact, and yet a well-known experience, to find that bacteria may live dormant in ice for prolonged periods, and that infection may be carried through ice, but it is not so generally recognized that some bacteria prefer to grow on ice. Micro-organisms, as a rule, are capable of resisting a low temperature when their ordinary activities cease, and they tend, either as single units or in clusters, to throw out a mucilaginous protein substance for their protection. Ravenel, Macfadyen, and Rowland have demonstrated that several bacilli will bear exposure for a few days to the temperature of liquid air (—192° C. to —183° C.). More recently it has been proved that certain bacteria actually survive the temperature of liquid hydrogen (—252° C.), applied for so long a period as ten hours. Bearing in mind such experiments conducted *in vitro*, we could understand that certain organisms carried by dust-motes to the vicinity of the south geographical pole (at an altitude of approximately 10,000 ft.) could retain their vitality in a temperature of —100° C. (—148° F.), if ever the midwinter temperature descends to such a low limit. Certainly, in the prolonged insolation of the summer-time, some hardy organisms on the surface could thaw out, become free, and increase in numbers.

On the other hand, bacteria and their spores have almost a defined limit of resistance to heat—57° C., if applied long enough. Some germs are thermophilic, mainly those which live and multiply in warm-blooded animals; while others—in general terms, the bacteria of the sea, the soil, and the air—prefer the mean temperature of their environment.

In the Antarctic—and the same hold goods of the Arctic regions—there is a definite fauna, comprising in the former case the various species of seals, whales, and birds and their parasites, insect-like mites of the mosses, rotifera, and a fairly prolific marine life. The flora of the south is summed up in the lichens, mosses, and algæ, the last-named having a vast distribution amongst the ice encircling and adhering to the continent. Primordial, lowest of all, and standing as an evolutionary basis of the animal and vegetable kingdom

*From *Nature*.

[1] "Bakteriologische Studien wahrend der Schwedischen Sudpolar-Expedition (1901-3)." (Stockholm, 1908.)

[2] Deutsche Sudpolar-Expedition, 1901-3. "Untersuchungen uber Meeresbakterien und ihren Einfluss auf den Sloffwechsel in Meere."

[3] "Notes on Antarctic Bacteriology." (Edinburgh, 1912.)

[4] "Scott's Last Expedition," vol. 1., p. 211. (1913.) We have been unable so far to confer with Dr. Atkinson with reference to his actual results and general conclusions.

[5] The Western Party, under Mr. F. H. Bickerton, discovered a small piece of rock on the snow at a height of 3,000 ft., 17 miles southwest of the Hut in Adelie Land. This was afterwards identified in Melbourne by Prof. Skeats and Mr. Stillwell as a meteorite.

are the bacteria, which we may presume to say are universal—clinging to the myriad dust-motes which float from the north; descending in snow on the Antarctic plateau; paralyzed for long winter months; active and acclimatized in the liquid thaw of summer; segmenting or sporing in their multiplication; dormant again in the inter-crystalline canaliculi of the *névé* and ice, and free once more to live and increase in the viable reticulum of the glacier. Such a speculative theory may be the key to their cycle of life in Antarctica.

Liquid containing salts in solution does not completely freeze at a temperature of 0° C. (32° F.), and this factor is very important in the maintenance of low and higher forms of Antarctic life. The late Mr. James Murphy[6], of Sir Ernest Shackleton's British Antarctic Expedition (1907-9), has contributed some unique evidence of the habits and powers of resistance to cold exhibited by the rotifers and water-bears.

"To test the degree of cold which they could stand, blocks of ice were cut from the lakes (saline) and exposed to the air in the coldest weather of the whole winter. By boring into the center of the blocks we found that they were as cold as the air. A temperature of —40° F. did not kill the animals.

"Then they were alternately frozen and thawed weekly for a long period and took no harm. They were dried and frozen, and thawed and moistened, and still they lived. At last they were dried, and the bottle containing them was immersed in boiling water, which was allowed to cool gradually, and still a great number survived. . . .

"Such is the vitality of these little animals that they can endure being taken from ice at a *minus* temperature, thawed, dried, and subjected to a temperature not very far short of boiling-point, all within a few hours (and a range of more than 200° F.). . . ."

It would seem that bacteria were the ideal denizens of an environment where, for the greater part of the year, all visible life is banished, and where their minute size, protective changes of form, and versatile reaction to moisture, low temperature, and concentration of salts would be most advantageous for existence. The bacteria caught up in the frozen sea within the liquid sludge of cryohydrates, which circulates between the crystals of fresh-water ice, learn to live, and probably multiply, in a medium of much higher concentration than the ocean to which they are accustomed.

The question now seems naturally to arise: How are we to explain the existence and multiplication of bacteria in ice? And to satisfy such a query we should endeavor to discover what is the ultimate composition of ice, how the crystals of ice are inter-related, and what are the intimate changes which occur in a descending or rising temperature.

We refer to Mr. J. Y. Buchanan[7], formerly of the *Challenger* Expedition (1874), for the most modern views of ice-formation.

As a result of many exhaustive experiments on the changes which occur in freezing non-saturated saline solutions, he finds that the crystals formed by freezing a saline solution are in their ultimate constitution free from salt. That is to say that "the crystals formed in freezing a non-saturated saline solution are pure ice, and that the salt from which they cannot be freed does belong to the adhering brine." Therefore, we may imagine that when sea-water freezes the primary solidification which takes place is of the fresh-water content, the salts in solution being rejected into the channels which now exist between the pure crystals. As the temperature is still further reduced, accretions of pure ice go to the crystals, and the brine, still further concentrated, remains in the channeled meshwork.

In the case of the glacier-ice of Adelie Land, which we wish particularly to consider, one would expect the ice to be very pure; in fact, the superimposed layers formed from the snow which has fallen should be, presumably, as fresh as distilled water. But assuming, as we do, that a large amount of aerial dust is distributed over the South Polar plateau, and that atmospheric gases are combined with the snow, the ice contains mineral constituents, without doubt, in much more dilute solution than is present in the rain-water of a more temperate climate. And, considering that this contamination by dust-motes has gone on for countless æons, the whole thickness of the polar ice-cap is impregnated with minute foreign bodies.

On dissecting a piece of the glacier we find that a disintegration of the interlocking grains, similar to that which occurs in upturned slabs of sea-ice, takes place on its exposure to the warmth of the sun or to a temperature just below the freezing-point of fresh water. As Buchanan says: "Under the influence of the sun's rays the binding material melts first, the continuity of the block is destroyed, the individual grains become loose and rattle if the block be shaken, and finally they fall into a heap. A block of glacier-ice is a geometrical curiosity. It consists of a number of solid bodies of different sizes and of quite irregular shapes, yet they fit into each other as exactly and fill space as completely as could the cubes referred to above."

Buchanan made his studies of ice on the Alpine glaciers, which, in comparison with the ice-sheet of Antarctica, move rapidly, and, of course, are grossly contaminated by soil, rock and dust. Still, one of the first phenomena we remarked when stepping on to the ice-foot at Cape Denison, Adelie Land, was the large amount of granular rubble which formed the surface of the glacier. In other words, the summer sun had thawed out all the cementing channels, and the crystals lay melting in a clear slush of liquid.

To a living organism a few micro-millimetres in length, a block of glacier-ice not completely solidified would be a veritable labyrinth of minute tunnels filled with liquid containing salts in solution. In every direction the tunnels would be viable, so that a single bacterium might easily pass from top to bottom of the block. The same lump, as an integral part of the glacier, would still be perforated with devious and circuitous passages, inosculating with others in the surrounding ice, but the watery contents of these passages would follow laws of movement dependent upon gravity, the slope and movement of the glacier, the presence of small seams and cracks in the ice, and the gradient of temperature from above downwards.

Sufficient has been said to indicate that if in the section of ice we are considering the temperature approaches to freezing-point, the channels of adhering fluid which encircle the crystals would permeate the glacier down to a definite point where, if the mean annual temperature were low enough, the ice would be solid and impervious. We are led to suppose from Buchanan's observations that the critical temperature of solidification may be as low as —13° C., though in Antarctica, where the ice is purer, it should be 4° or 5° higher. Granting that such a temperature may be several degrees from the actual truth, we may at least be sure that for 5° below the freezing-point of fresh water the glacier-ice of Antarctica is pervious to bacteria, and contains a medium suitable for their reproduction.

In Adelie Land the mean annual temperature at sea-level lies between —15° and —20° C., but on mounting the plateau which falls steeply to the coast, the temperature descends at the rate of almost 4° for every 1000 feet. In the summer-time the shade temperature registered on several occasions 5.5° C. (40° F.), and for three months at least the temperature, except for unusual fluctuations due to blizzards, never fell much below —10° C., and was very often close to 0° C. Considering, too, that there is a very appreciable amount of sunshine between the equinoxes, the period during which bacterial life and growth would be possible might be extended, during a favorable summer, up to four months. The action of sunlight is of paramount importance in promoting a thaw throughout the ice canaliculi, especially when we remember that the shade temperature may register 0° C. at the same time as the thermometer in the sun rises to 16° C.

The important point at issue is that the northern slopes of the glacier fall towards the sea at such an angle that the rays of the sun for some months during the summer are normal to the surface, thereby increasing the intra-glacial thaw, and for short periods causing the temperature of the whole mass in the lower latitudes to rise within a few degrees of freezing-point, the optimum temperature of the micro-organisms of ice and snow. At the south geographical pole, elevated to 10,000 feet, the obliquity of the sun's rays and the low temperature would not encourage bacterial life except in the surface layers of snow, and that only for a few weeks at the summer solstice. Assuming that the greater part of the continent is at a more or less uniform height of 6000 feet, we should conclude that the organisms which descend from the air are, when buried to a certain depth, wholly deprived of a free-swimming existence, until in the plentitude of ages they arrive at that northern boundary where the summer thaw begins.

It will be apposite now to review the few observations which were made on snow before passing to a few remarks on the meteorology of the southern hemisphere.

(1) Gram-positive cocci and gram-negative, sporing bacilli grew in culture from snow of a sastruga or snow-wave one-third of a mile southeast of the Hut.

(2) On three occasions when falling snow was gathered in a sterile basin, elaborate precautions having been taken to prevent contamination, the thawed-out samples showed under a cover-slip cocci, motile bacilli, and, invariably, zooglœa masses of bacteria in moderate numbers. Diplococci, and occasionally cocci, were observed to be invested by a pale capsule. In one case doubtful organic matter in the form of vegetable cells was noted.

(3) A *glucose agar slope* culture of falling snow showed a few small greyish colonies, which were not examined.

Slender as these results are, they become of more importance when correlated with the many positive findings made in glacier-ice—the vast repository of the falling snow. They are meaningless, too, unless we consider the probable origin of the bacteria which cling to the crystals of snow.

Regarded simply, the circulation of air in the southern hemisphere has certain main characteristics—a widespread uprush from equatorial, tropic and sub-tropic zones; a continuous flow at a high level towards the southern continent; a subsidence of successive layers of cool air, increasing in density and coincident with a rising barometric pressure; a concentration of air at high barometric pressure over the vast crown of lofty Antarctica; a relief of pressure in the torrential bursts of blizzards through to the low-pressure belt of the Southern Ocean, and, in wide terms, the genesis of a low equatorial return current modified and deviated by such factors as earth-movement, latitude, disposition of island, sea, and continent, and configuration of the land.

Bacteria or their spores may be found in the atmosphere free, incorporated with minute particles of aqueous vapor, or clinging to small foreign bodies. With these foreign bodies or dust-motes we know that they ascend under the impetus of rising equatorial air into the atmosphere to a considerable height, until at length they come under the influence of the great poleward-flowing current. The bacteria meanwhile have cooled, become paralyzed, and, either singly or in segregated masses, thrown out their protective capsule of protein material. They travel to the Pole, and here are frozen to spicules of ice or with the dust which has conveyed them are attached to crystalline snowflakes, sinking lower with the descending strata of air, and alighting at last on the surface of the plateau.

And now, sparse or in numbers, the frozen organisms, extruded with the dust-mote they accompanied to the periphery of the nuclear snow-crystal, commence a new life-history.

When the snowflakes—on the plateau of Antarctica snow is mostly in the form of sago-like granules—have recently fallen, they lie together in soft, downy, flocculent heaps enclosing, in proportion to the space they occupy, a large volume of air. Under the influence of gravity and the pressure of the wind, and in dependence, too, on the temperature and humidity of the air, the snow becomes denser and more compact, the enclosed air is expelled, and the snow-crystals increase in size. Thus we may conceive that the bacteria tend to be expelled into the interstices between separate crystals, where they await the time when the temperature will rise sufficiently to provide a liquid medium in which their life and species may be renewed. If the temperature still remains too low for liquefaction of the comparatively impure snow adhering around the primary pure crystal, the slow metamorphosis of the snow into *névé* goes on under more or less dry conditions.

In conclusion, if we trace out briefly the subsequent history of these bacteria of ice and snow, we see them in the slow northward surge of the glacier set floating in ice-tongues and bergs of the Antarctic Ocean, where they gradually thaw out and probably become accustomed to the salinity of the sea. They circulate throughout the immense volume of water, clinging to the plankton of the surface, traveling to various depths, reaching, maybe, the ooze in company with sinking foreign bodies. They migrate in the vast, moving ocean currents towards northern lands, where some remain as marine bacteria; others enter the mouths of rivers and become adapted to life in the fresh-water medium they knew in Antarctica, while still others are stranded on the littoral, whence, in a dry condition, they may be transported by wind to a new soil, assuming, perhaps, the characters of anaerobic bacteria. The cycle—centuries or geological periods in duration—begins once more when, in a temperate zone, the descendants, by an endless gamut of fusion or sporulation of the original organisms, rise on dust-motes and rejoin again the bacteria of the upper air, once more liable to enter the current flowing continuously towards the southern pole of the earth.

[6] "The Heart of the Antarctic." By Sir E. H. Shackleton, C.V.O. Vol. ii., p. 238. (London, 1909.)

[7] "Ice and its Natural History."

A Short-Crowned Daffodil—"built on the plan of 4" instead of 3. There are 8 petals, 8 stamens, and 4 divisions to the ovary. The 4 stigmas plainly show in the picture

"Doubling" of Crocuses and Daffodils

Francis M. Fultz

I HAVE long been interested in watching the "doubling" tendencies of flowers. Among those which have particularly claimed my notice are the Crocuses and Daffodils.

The most interesting phase of floral life to me is the rigidity of its conformance to certain set number schemes. It has always been so from my first introduction to plant study. This is probably what first interested me in the "doubling" tendencies of flowers. I first began to notice this departure from type in the Crocuses. From there it extended to other forms of the Lily Family, and then gradually to the entire floral field. But the Crocuses and Daffodils have always especially claimed my attention.

Most of my life has been spent in the Middle West, in a region of severe winters and warm summers. There the Crocus is a spring flower—March or April—blooming before the frost has entirely left the ground, and often while there are still snowdrifts in fence corners and other protected places. In fact they bloom so early there that they are sometimes caught by April snow flurries, although they are very seldom injured. I remember seeing a fine border of them once nearly buried by an April snow, out of which they serenely peeped, the white ones shaming the snow for purity, and from which they emerged without a trace of frost —for the snow was a "warm" one. In that region the Crocuses do not exhibit the "doubling" tendency to anything like the extent that I have seen since coming to the Pacific Coast.

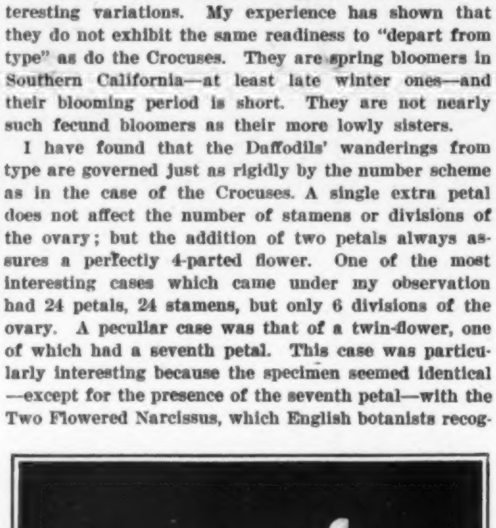
In Southern California the Crocuses are fall bloomers —or, at the latest, early winter ones. They may come along by September, but anyway as early as October or November. And their blooming fecundity is many times that which they show in rigorous climates. A ten-foot row will keep a household supplied with flowers for a month or more. They are exhuberant in their growth, and seed profusely. They are exhuberant not only as to profusion of flowers, but also as regards size and shape of the individual blooms. They seem to be "just aching" to escape from the six-petaled restriction placed upon them by Mother Nature. And a goodly number of them succeed in doing so—and also in transmitting to their offspring the acquired trait.

My particular interest in the vagaries of the Crocuses centered in noting to what extent the number scheme still controlled them when they departed from the 3-parted one set them by Nature,—or perhaps I should say, *guided* them. I found some of them adding a single petal, which almost always took place without the addition of an extra stamen, and always without any modification of the pistil. This in no essential way affected the number scheme. A more frequent variation was the addition of two petals, thus making an 8-petaled flower. And these nearly always had 8 stamens and a 4-parted ovary. These might be said to be "running true to form"—two petals and two stamens to each division of the ovary—although lilies are considered as being "built on the plan of 3,"

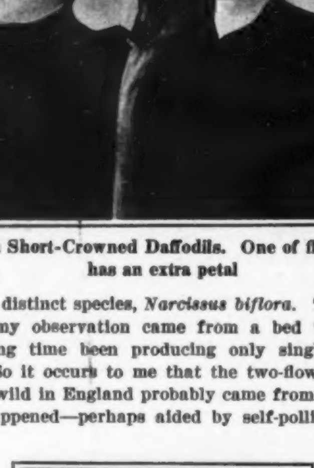
There was ocasionally one with 9 petals. But 10 was a more frequent number, and I found several cases where there were 12. In the cases of 9 petals, the ninth one seemed to be an extra to a flower otherwise built on the plan of 4, there being 8 stamens and 4 stigmas. In the cases of 10 and 12 petals the flowers were perfectly consistent in their make-up: the former always had 10 stamens and 5 stigmas, while the latter had 12 stamens and 6 stigmas. This shows that the number scheme imposed by Mother Nature was holding them strictly in line, although they were being allowed considerable latitude in the matter of floral display.

Although my observation of the "sporting" proclivities of the Daffodils has not been so extensive as with the Crocuses, yet I found among them some very interesting variations. My experience has shown that they do not exhibit the same readiness to "depart from type" as do the Crocuses. They are spring bloomers in Southern California—at least late winter ones—and their blooming period is short. They are not nearly such fecund bloomers as their more lowly sisters.

I have found that the Daffodils' wanderings from type are governed just as rigidly by the number scheme as in the case of the Crocuses. A single extra petal does not affect the number of stamens or divisions of the ovary; but the addition of two petals always assures a perfectly 4-parted flower. One of the most interesting cases which came under my observation had 24 petals, 24 stamens, but only 6 divisions of the ovary. A peculiar case was that of a twin-flower, one of which had a seventh petal. This case was particularly interesting because the specimen seemed identical —except for the presence of the seventh petal—with the Two Flowered Narcissus, which English botanists recognize as a distinct species, *Narcissus biflora*. This specimen of my observation came from a bed which has for a long time been producing only single-flowered forms. So it occurs to me that the two-flowered form growing wild in England probably came from a "sport", which happened—perhaps aided by self-pollination—to breed true to the variation. And that in this way the bi-floral trait became fixed.



Twin Short-Crowned Daffodils. One of flowers has an extra petal



A 9-Petaled Crocus. The ninth petal is an extra one, as the flower has 8 stamens and 4 divisions to the ovary

A Short-Crowned Daffodil with 24 petals, 24 stamens, and 6 divisions to the ovary

One of the oddest instances of "doubling" which has come under my notice was that of a member of the Arum Family, the common Calla—often wrongly called "Calla-Lily." The specimen in question had two perfectly developed spathes—instead of one, the normal form—but only a single spadix. The variation from type was not merely incidental to a single flower—and therefore a clear accident—but harked back to some constitutional vagary of the plant which bore it, for this plant from time to time has produced two-spathed flowers, although most of its blooms have been of the normal type.

Protection Against Aircraft

IT is considered desirable to establish batteries of special guns as a means of protection against marauding aircraft wherever the propinquity to enemy bases makes attacks from the air possible; and such batteries will be found both in the vicinity of the battle lines, and in many of the cities of France and England. As far as can be ascertained, however, the results of the activities of such batteries have not entirely met the expectations of the authorities, for an aircraft, even a Zeppelin, offers a very small target at the height at which they usually fly, and, in addition, this little speck in the sky is moving at a speed in the neighborhood of 100 miles an hour; so it can readily be appreciated that a hit is largely a matter of luck.

Recognizing these conditions the present method of using anti-aircraft guns is to establish a barrage across the course of flight; and this has been found fairly effective in discouraging the efforts of the invaders, even if it is expensive in ammunition and few hits are made.

One of the drawbacks to the use of these batteries in or near crowded cities is that the fragments of all the shells fired must come back to earth again, and there may be some unexploded shell among the lot, and this shower of metal constitutes a by no means insignificant bombardment in itself. It is as much for protection against this shower of metal as against the missiles of the enemy that the inhabitants of the neighborhood are warned to take to safe shelters.

Theory of Action of Sand Filters

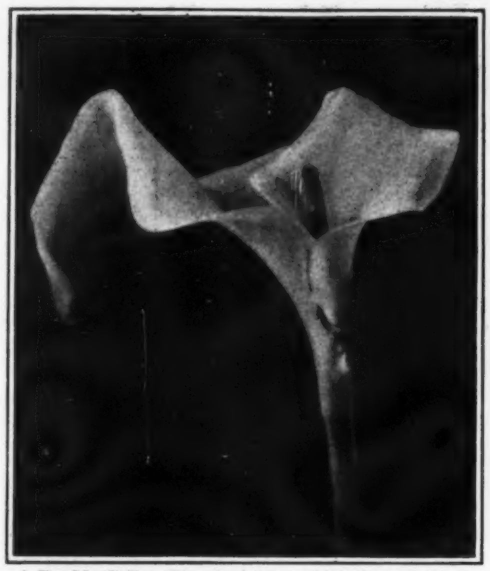
KISSKALT'S view (J. Gasbeleucht, 1917, (9), that the action of the sand filter in water purification is biological and due to the destruction of bacteria by other organisms is contested on the basis of experience at Zurich waterworks where the lake water is filtered in two stages through sand. The first retains most of the fresh water planktons but allows some of the bacteria to pass. The bacteria are retained by the second filter and at the surface, so that at a depth of 10 cm. the number per c. c. has already fallen to one-tenth. Furthermore the retention of bacteria is satisfactory even when there are considerable fluctuations in the number of bacteria in the water, and it is concluded that the process is mechanical rather than biological.—*Note in J. Soc. Chem. Ind. on an article by L. Minder in J. Gasbeleucht.*

Coal and the Cult of the Skin

MANY times already in the course of the war the medical profession has been invited by Government Departments to use its influence in bringing home to the people at large the hygienic lessons rendered urgent by the times we live in. The most recent of these appeals emanates from the Office of the Coal Controller, who warns us that the country is faced with a serious shortage of coal. The outlook today, he says, is much graver than is generally realized, the deficit amounting to something like 36 million tons of coal. Coal is the principal and irreplaceable source of power, whether for offense or defense; it is the raw material from which gas, electricity and steam alike are produced, and a reduction in its supply beyond a certain limit would put an end to essential industries. The Coal Controller draws the lesson that self-denial is called for, that every private consumer should be content with three-quarters of the ration which is legally his due; and he appeals to medical men to help him in enlisting the services of every man, woman and child in the country in a united effort of economy in the use of coal. To us it appears that the counsel of the medical man might often be of the first value.

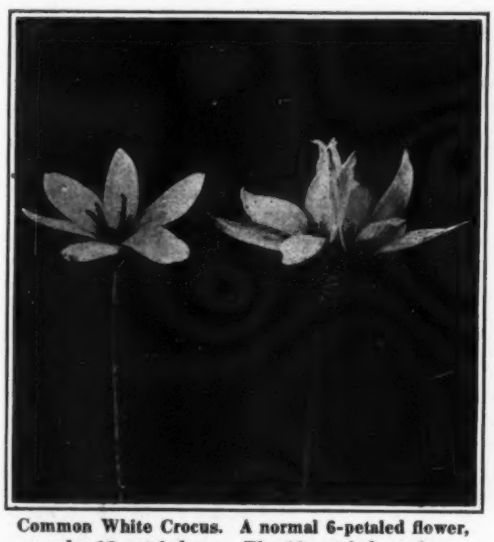
It would be easy to enlarge on the hardships which any further restriction in the already scanty coal-supply will involve for the private citizen. The hardship might indeed imply some danger for the old and infirm as well as for the young child, were it not for the prospect already held out of an increased allowance in respect of both extremes of life. We are concerned here rather with the average citizen and his vital needs. Fuel economy affects us chiefly in two directions. In warmer weather, such as at present prevails, our coal is used to cook and, with a growing mass of the population, to heat water for washing. In the winter, to which the Controller is looking forward with anxiety, coal is used in addition to raise the temperature of the home atmosphere above that of the outside air. Economy of coal in relation to the preparation of food is a familiar subject to those who have studied it practically. And it should now be known to every man, woman or child that to cook any kind of viands they need only be raised to the required temperature by the active use of fuel, when they can be maintained at or near this level by insulation in one or other of the many ways, of which the newspaper cosy is the cheapest type. Alas! this simple fact, fundamental for economy, appears to be hidden from many people. The continuous consumption of coal or gas throughout the day in a private house for cooking either implies a lamentable want of enterprise or a lack of that feeling for the needs of others enjoined on us by proclamation. The using up of fuel to heat water for bathing purposes continues on an enormous scale. Water is very costly to heat, and this attribute of water makes it an admirable medium for circulating warmth about the house, but there is an obviously large waste of potential energy in allowing successive instalments of 20 gallons each of slightly soapy water at 100° F. to run down the bath-room waste. Nothing is more certain than that the daily full hot bath is unnecessary either for cleanliness or for the maintenance of the proper function of the skin. The frequently repeated use of soap and hot water over the whole body removes from the skin the natural fat which is itself a desirable insulating material. We may admit without shame that the hot-bath habit is in the nature of a pleasant indulgence for those citizens whose ordinary avocations do not bring them into close association with dangerous materials, which have to be regularly removed from the skin by drastic ablution.

Turning to winter conditions, it is in the maintenance of the difference between indoor and outdoor temperature that coal is principally consumed in the private house, and the consumption runs up rapidly as the difference becomes greater. In the summer, when indoor and outdoor temperatures are roughly equal, we wear the same clothes both in and out. As the outdoor temperature falls in autumn most of us temporize by dressing more warmly before resorting to artificial heat. The point at which we give in to the cold varies greatly. In Vladivostok there is little to be gained by delaying the day, since the winter cold is so intense that the resident makes no attempt to meet it half-way, but lives indoors in summer clothes at an artificial summer temperature, encasing himself thickly in the skins of beasts when he stirs abroad. But the climate of this country, much as we abuse it, has this in its favor; that the difference between average summer and winter temperature is only slight, so that the fate of the tuberculous patient or the wounded soldier unprovided with artificial heat is no more to be pitied than that of his



A Double Calla. The plant from which this specimen came produces from time to time such a flower, although most of its blooms are normal

comrade in the trenches. Those who think otherwise have not sufficiently realized that the skin is not a mere protective crust but an organ with functions as definite as those of the heart or the kidneys—functions with a wide range of adaptation which develop with appropriate use and respond in proportion to demand. Fortunately, in the recent rise of interest in the maintenance of infant health the public has been receiving object-lessons of the first value along these very lines. Skin training, as we know, plays a large part in the education of the infant, and in the modern nursery the judicious use of cold water and of friction leads on



Common White Crocus. A normal 6-petaled flower, and a 12-petaled one. The 12-petaled one has 12 stamens and 6 divisions to the ovary

to an indifference to the impact of cold air currents and an absence of that sensitiveness which is a nuisance to its owner and a serious handicap in the business of life. "I am cold but not suffering," is the expression of one so trained. It is perhaps unfortunate that the sensations of heat and cold should have any agreeable or disagreeable tone attached to them. The surface temperature of hands and feet varies greatly in different people, the same temperature to some being a discomfort, while to others it is a matter of indifference. The sensation of heat and cold provoked in the skin is doubtless a physiological response designed, like that of pain, to call attention to the need for adjustment. But the sensation of cold is largely influenced by the condition in which the skin is maintained. If its possessor keeps it in a more or less moist and sodden condition, at the same time carefully removing the natural non-conducting fatty material, heat is transmitted freely through it, and the need is felt for more external warmth. The pampered skin becomes ever more imperious in its demands. It should be borne in mind that each one of us lives, not so much in the climate of the town or even of his house, but in the atmosphere within his own clothes.

We do not suggest that every individual should study the functions of his skin, seeking to discover for himself the limits of compensation within the bounds of safety. But we think that medical men may be of the greatest assistance to their charges by explaining to them that sensations of cold which they find disagreeable can be largely mitigated by common-sense precautions, and will tend to disappear spontaneously when regarded rightly.—*The Lancet.*

Nitric Acid from Nitrogen Oxide

IN most of the modern furnace processes for the fixation and oxidation of the atmospheric nitrogen, nitric oxide NO, is produced which, on being mixed with air, takes up more oxygen with the formation of red-brown vapors of NO_2; these vapors are absorbed by water yielding both nitric acid HNO_3 and nitrous acid HNO_2; the latter is decomposed, giving again NO and some more HNO_3. None of these reactions can easily be controlled in practice, however. The NO gas leaves the electric or other furnace in which it is prepared hot and has to be cooled considerably below 600 deg. C. before it will effectively combine with the oxygen of the air; that cooling requires large spaces. The absorption of water again is incomplete and calls for large towers packed with stoneware, coke, etc., in which the gas meets the water descending through the stoneware balls or fragments; there is thus much pumping, and the resulting acid is after all diluted and has to be concentrated. Finally there is generally loss of nitrous vapor with the excess of air to be used. Many processes have therefore been tried to hasten and facilitate the reactions, and some recent experiments on these lines conducted by G. B. Taylor, J. H. Capps and A. S. Coolidge, of the U. S. Bureau of Mines, are described in the Journal of Industrial and Engineering Chemistry of April last. In the first instance they tried to find a better absorbent than water for the nitrous vapors. A mixture of sulphuric acid and chromic acid seemed promising, as the chromic acid would further oxidize the oxides and might be recovered. But they observed that the acid mixture had to be used at the very inconvenient temperature of 150 deg. C., and that the recovery of the chromic acid from the chromium sulphate formed could not profitably be carried out by electrolysis, though it can be effected with the aid of platinum electrodes and alundum diaphragms. Electrolytic oxidation of the nitrous vapor dissolved in sulphuric acid alone also failed. They therefore returned to absorption by water and diluted nitric acid. They packed five towers with coke which was flushed at intervals with diluted nitric acid; the first of the five towers was left empty to serve as oxidation tower. They found that they could absorb 85 per cent. of the acid in the first three towers, and that an increase of the number of towers for the purpose of diminishing the loss of acid was hardly advisable. The upper portion of each tower was left empty to provide further reaction space, for the NO and oxygen must be properly mixed to combine, though the reaction itself is rapid under suitable conditions. As the rate of NO gas supply was increased from 1.25 cub. ft. per minute to 2.5 cub. ft. and 4 cub. ft., the efficiency of absorption fell from 98 per cent. to 95 per cent. and 91 per cent., but the total recovery of HNO_3 increased from 23 lb. to 44 lb. and 68 lb. in 24 hours. Thus the rate of gas flow should not be too slow. At the same time the excess of oxygen (over the theoretical amount necessary for the complete oxidation) should not fall below 5 per cent, nor be too great, lest the gas mixture be too diluted, and too much fine mist of acid vapors escape from the towers. This loss of acid mist was much reduced by the aid of Cottrell's precipitator; the vapors were sent up a glass tube in which platinum wire, stretched axially, served as the one high-tension electrode, the other electrode, wire coiled round the tube, being earthed. The experimenters conclude by recommending that very ample reaction space should be provided, and that atomizing sprayers be used, the fine mists of acid finally to be precipitated by the Cottrell apparatus. The use of the electric precipitators is certainly spreading, and they have done good service; but it must also be acknowledged that they do not appear to clear gases and mists of the very finest particles so well as of coarse particles.—*Engineering.*

Water Power In Germany

PROFESSOR HELBFASS estimates the available water power in Germany at 11.4 million horse-power, of which only about four millions is yet utilized. In 1910 the proportion utilized was only 5 per cent of the steam power produced, while in France the percentage reached 40. Hence German industry has an abundant source of power to fall back upon for its future developments.

A Fifty-Year Retrospect*

Of Naval Marine Engineering in the United States

By Rear-Admiral C. W. Dyson, U.S. Navy, Member American Society of Naval Architects

THE armed forces of democracies ride on the crest of the wave of popular approval only in times of national peril. The peril past, the Army and the Navy are forgotten, save by a few, and these forces are practically compelled to fight, if not actually for existence, at least for sufficient support to maintain a nucleus about which efficient forces may be again built, if time permits, when another national emergency arrives.

At the time of my entrance into the U. S. Naval Academy as a cadet engineer, October 1, 1879, the Civil War was buried under fourteen years of peace, during which time the Nation had been taken up with the mighty problems of reconstruction of the Union, and of the rebuilding of industries and of private fortunes which had been wrecked in the turmoil of the strife. The Navy, as well as the Army, was withdrawn from the spotlight of the public stage and, being hidden in obscurity, was forgotten.

The vessels on the active list of the Navy were mostly relics of the period antecedent to the war and of the war period, and included among them one steam frigate fitted with side wheels. The building ways at the navy yards were occupied by wooden hulls laid down during and immediately subsequent to the war, but which, due to lack of appropriations to complete, were far advanced in decay at the period of which I write. At several of the shipyards of the country were the iron hulls of five monitors, some of which had already been launched, but all of which were waiting for turrets and machinery, which were not forthcoming on account of lack of money.

In order to maintain the small number of ships we had on the Navy list it was necessary, in some cases, to rebuild the vessels around a small piece of the original keel, as Congress would approve appropriations for repairs, but practically none for new construction, and, therefore, this rebuilding was effected under the head of necessary repairs.

Some small amount of new construction had been carried on, however, and in addition to the few *ante bellum* and *bellum* craft there were four wooden steam sloops, three steel steam sloops, and one wooden steam frigate, the *Trenton*, on the Navy list, which only dated back to 1876 and '77.

The older engineers of the Navy did their share in the work of development, but they were growing old and disappearing rapidly from the active field, so that the brunt of the full development of our naval machinery as it exists today fell upon the shoulders of these few Naval Academy classes who have been in the battle from its inception. How well they have carried out their task is testified to by the efficiency now being demonstrated by our vessels of all types actively engaged in actual war service.

NAVAL ENGINEERING SUBSEQUENT TO THE CIVIL WAR

In 1863 the Navy Department had designed and had laid down several cruisers whose maintained sea speed was specified to be higher than that of any vessels, naval or merchant, afloat. The first of these vessels was not completed until 1868. This was the *Wampanoag*, the most celebrated in marine engineering history on account of the phenomenal results obtained, phenomenal in those days as compared with existing vessels. The machinery consisted of two single-cylinder simple engines, of 100 inches diameter of cylinder and 4 feet stroke, direct acting, and connected to the main propelling shaft by multiplying gearing, the designed revolution of the engines being 30, piston speed 240 feet per minute, revolutions of the propeller shaft 60. The gears were made with wooden teeth in order to deaden the noise.

On trial the results obtained were as follows:

Duration of trial ....37½ consecutive hours

Wind and sea	Fresh wind abeam	Moderate sea on quarter
Average speed, knots............	16.71	11.39
Average revolutions, engine........	31.06	21.36
Average revolutions, propeller......	63.673	43.78
Boiler pressure, lbs. per sq inch....	31.97	20.69
Coal per hour, pounds............	12,690	3,474
Coal per day, tons..............	136	37.2
Knots per ton of coal............	2.95	7.34+
I. H. P.	4,048	

*Read before the Am. Soc. of Naval Architects.

What these results mean will be more fully appreciated when it is considered that this maximum speed was not attained in the British Naval Service until eleven years later, 1879, with the large despatch vessels *Iris* and *Mercury*; in the merchant service in 1879, with the Guion liner, *Arizona*; while in our own Naval Service a period of 21 years elapsed before this speed was again equalled.

The *Wampanoag* and her sister ships were born too soon. They were surveyed and condemned as unfit for the Naval Service within a year of their trials, among the reasons given for this action being "excessive amount of fuel burned" and "the grate surface exceeded the area of the midship section of the ship." Viewing the fuel consumption in the light of today, the first reason appears childish, but it must be remembered that, at the time of these vessels, the leading spirits of the Navy were the developments of the days when sails as a motive power were supreme, and machinery was only looked on as an auxiliary to help out in time of calm or when the use of sails was impracticable. The second reason appears peculiar today, but may have had some connection with the subject according to the viewpoint of those days of long ago.

The machinery of the *Wampanoag* was designed by the late Commodore B. F. Isherwood, U. S. Navy, who at that time was Engineer-in-Chief of the Navy. He was subjected to a great amount of criticism at the time but he was ahead of his time and his accomplishment was not appreciated at its full value.

The first decided and permanent step in advance in marine engineering in our Navy occurred in 1871-1874, when it was determined to throw away the two simple cylinders of each of six sets of engines which had been built for installation in six old sloops being rebuilt under the head of repairs, and to fit in place of them a high and a low-pressure cylinder. This was the first appearance in our Service of the compound engine.

These engines were of what was known as the "Isherwood" type. They were horizontal, back acting, with the cross-tail guides located under heavy rectangular cast-iron condensers on the opposite side of the ship from the cylinders. The main circulating, main air, and main feed pumps were all of the reciprocating type, worked directly by rods taking hold of lugs on the side rods connecting crosshead and cross tail. The stroke of the engines was 42 inches, the revolutions about 50, giving a piston speed of 350 feet per minute. The steam pressure at the boilers was 80 pounds per gage. This rise in pressure from the 30 or 40 pounds carried with the old simple engines necessitated a departure from the rectangular type of boiler which had been used in the past, and the adoption of boilers of the cylindrical type. These cylindrical boilers were classed as "Compound" boilers, but were the same as the well-known "Scotch" boiler of today.

In 1873 Congress passed an act authorizing the construction of eight vessels of war. These were the vessels referred to earlier in this lecture as coming into the Service in 1876-77. The most noteworthy thing in this act of Congress was the fact that the act required that these vessels were to be "steam vessels of war, with auxiliary sail power." This proviso indicates the development of a view-point that was occurring and is one of the first signs of a full appreciation by Congress and by the naval authorities of the value of the steam engine as a main power unit for marine propulsion.

The three steel sloops were fitted with engines of 560 i.h.p., those of the four wooden ones with 800 i.h.p., while the wooden frigate was given 3000 i.h.p. All of the engines were of the then well-known Isherwood type, as already described, the sloops being two-cylinder compound while the steam frigate was three-cylinder compound, all of the engines being horizontal.

Up to this time and for several years later all engines for our fighting ships were made horizontal in order to keep them below the water line of the vessel and thus insure a certain degree of protection against gun fire. The engineer departments of the ships were of the very simplest type, practically all principal pumps being operated from the main engines. The auxiliary machinery was very limited in amount, there being no such machines or apparatus as blowers, dynamos, evaporators, ice machines or even sanitary pumps. Distilling condensers were fitted, but the steam for them was taken directly from the main boilers and the fresh water thus made was used only for officers bathing, for cooking, and drinking purposes.

Simple as were these machinery installations, I still have a vivid picture in my mind of the engineers of those days walking around thoroughly bowed down by the weight of responsibility carried on their shoulders. A junior officer of today would feel very much injured should he be ordered to duty as chief engineer of one of these old vessels, some of which are still in active service, and wonder as to what was the trouble with his record.

In June, 1883, the Navy, while not dead, was moribund, but in that year occurred what may be styled

THE RENAISSANCE OF THE NAVY AND OF NAVAL MARINE ENGINEERING.

By 1883 the condition of the Navy had become so bad that officers were ashamed to take their vessels into ports where the vessels of foreign nations might be encountered, so antiquated were our ships, not only in appearance but in material of all description. During this year, however, the interest of Congress awakened from its long sleep of nearly twenty years, and the naval appropriation bill of that year carried in it a provision for the construction of four new vessels. These ships when built were known as the *Chicago*, *Atlanta*, *Boston* and *Dolphin*; the first three being protected cruisers and the fourth a despatch vessel.

The *Dolphin*, *Boston* and *Atlanta* were all single-screw ships, the first named having a two-cylinder, vertical, inverted compound engine of 2300 i.h.p. at 75 revolutions and 110 pounds steam pressure at the engines. Those of the *Atlanta* and *Boston* were similar in design to those of the wooden steam frigate of 1876, developing 3500 i.h.p. at 70 revolutions, with 90 pounds pressure at the engines, the piston speeds being 600 feet per minute for the *Dolphin* and approximately 500 feet for the two cruisers.

The questions of the design of the hulls and machinery of these four vessels, which formed the nucleus of our new Navy, were of such importance that in the appropriation bill a provision was made for a Naval Advisory Board to determine these important questions. As organized, this Board consisted of five naval officers, three being of the Line, one engineer and one naval constructor, associated with two civilian members, one of these being a naval architect while the other was a marine engineer, both being very prominent in their professions.

As can be seen, the Board was very conservative in the cases of the *Dolphin*, *Boston*, and *Atlanta*, but in the case of the fourth vessel, the *Chicago*, they allowed themselves to go to the other extreme in their desire to show something peculiarly American, and widely different from anything in the line of machinery that had heretofore been fitted in the vessels of any Navy. Anxious as they were to show progress, the engines which they adopted were remarkably like the engines which were fitted to a craft known as the *Stevens Battery*, thirty years prior to this time.

The civilian marine engineer was given practically full control in the determination of the type of machinery, due, as was stated by a member of the Board, "to the popular pressure to give the outside a chance."

The vessel was twin screw, with two two-cylinder compound engines, one to each shaft. The cylinders stood vertically on the bottom of the ship, piston rods passing through the upper heads and connecting by means of links to athwartship walking beams which connected through links to the crank shaft on the opposite side of the vessel. The engines had a stroke of 57 inches and were designed for about 70 revolutions when developing 2500 i.h.p. each, the piston speed being 665 feet per minute with a steam pressure at the engines of 90 pounds per gage.

The boilers were also of a peculiar type, there being five double-ended and two single-ended ones. They were cylindrical, return tube, with internal back connections. The boilers were set in brickwork and externally fired. There was one point of real advance made, however, and that was in fitting the vessel with forced draught, which had been installed in isolated cases in the past.

The life of the entire installation was short, it being entirely removed after seven years' service and replaced with inclined three-cylinder triple-expansion engines,

and a mixed installation of Scotch and of water-tube boilers, the latter being of the early Babcock & Wilcox type.

The supporters of sail power still being in the ascendant, although the signs of the times indicated their speedy downfall, these four vessels were all rigged powerfully, the *Chicago* being a barque, the *Atlanta* and *Boston* brigs, and the *Dolphin* a top-sail schooner.

The next vessels appropriated for, in 1885, the *Newark, Charleston, Yorktown,* and *Petrel*, marked a distinct era in the history of naval marine engineering in this country. The *Charleston* and *Petrel* were the last fighting ships designed with compound engines, while the *Newark* and *Yorktown* were the first vessels to be fitted with engines of the triple-expansion type. The engines still were horizontal.

The steam pressure carried in the boilers of the compound-engined vessels was 90 while in those having triple-expansion engines it had risen to 160. The piston speed of the *Charleston* was 690 feet per minute, while that of the *Newark* was 826. The power of the *Charleston* was designed 7500, that of the *Newark*, 8500. Both of these vessels on trial exceeded the record Navy speed of the old *Wampanoag*, the first in our Navy to do this after an interval of 21 years.

In 1883 electric apparatus for ship's lighting had been installed on the *Trenton*, the steam frigate of 1876, and she had the honor of being the first sea-going vessel, naval or merchant, to be so equipped. The *Yorktown* also marked the introduction of a new auxiliary. On her was installed the first evaporating set. In the vessels prior to the *Yorktown* and in those contemporaneous with her, the steam for the distilling condensers had been taken from the main boilers or from auxiliary boilers provided for this purpose and for general auxiliary work. On the *Yorktown*, however, special evaporating apparatus as it is known today was installed, and such apparatus was gradually installed on all vessels of any size in the Naval Service.

As the *Charleston* and *Petrel* marked the passing of the compound engine from general use in the Navy, so the *Newark* and *Yorktown* marked the coming of a new type, which lasted for many years. They may be said to have been the first of the

ERA OF THE MULTIPLE-EXPANSION RECIPROCATING STEAM ENGINE.

The engines of these two vessels were of the same type, three-cylinder, horizontal, triple-expansion. The *Newark* and *Yorktown*, copying the *Charleston*, which had introduced to us a new type of valve-gear, were fitted with a radial type of valve gear known as the Marshall. This operated with one eccentric and one eccentric rod and had the one good feature of maintaining constant steam and exhaust leads at all degrees of linking up. It had, however, the objection of a great number of joints which, after adjustment, required a careful resetting of the valve. The popularity of this gear was short lived and it soon disappeared from our designs.

In looking for the machinery designs for these vessels the Navy Department, not having been impressed with the designs carried out in the first lot of new vessels, went abroad for the designs for the machinery for the *Charleston*, and the designs were obtained from England. These were supposed to be the designs used for the Japanese cruiser *Naniwa-Kan*, but they were in reality made up as a composite set taken from four different vessels, the Italian cruisers *Etna* and *Giovanni Bausan*, the *Naniwa-Kan* and a fourth ship, supposed to be the Chilean cruiser *Esmeralda*. Upon attempting to fit this hodge-podge collection together numerous cases of interference occurred, but finally a satisfactory vessel was evolved, although before this was accomplished the original air pumps, which were of the horizontal, high-speed type, were discarded and air pumps of the vertical, inverted, overhead-flywheel type substituted.

The machinery of the *Petrel* was designed by the Navy Department while those of the *Newark* and *Yorktown* were the children of the brain and skill of Mr. Horace See, at that time the Designing Engineer for the Cramps Ship & Engine Building Company, the builders of these two ships, and to Mr. See belongs the credit for fathering the multi-stage expansion era in the Navy.

The year 1886 was a banner year for the Navy. The Naval appropriation bill for that year provided for one second-class battleship, one armored cruiser, one protected cruiser, the dynamite-gun cruiser, and one torpedo boat. Of these vessels four were practically new types of vessels in our Service, for the nearest approach to battleships we possessed were the large monitors already mentioned, of which at this time four were being completed; no such craft as the armored cruiser had existence with us. While we had had torpedo boats previous to this time, they had usually been either of the make-shift variety or of some disappointing freak type from which nothing could be expected. The dynamite-gun cruiser may be placed in the freak class. She was "wished" on us and was a failure, so far as her special function was concerned, from the outset.

The engines of the armored cruiser *Maine* and the dynamite vessel *Vesuvius* were designed by the Bureau of Steam Engineering of the Navy Department and the Cramps Ship and Engine Building Co., respectively, those of the torpedo boat *Cushing* by the Herreshoff Manufacturing Company, while those of the battleship *Texas* and of the protected cruiser *Baltimore* were purchased in England.

The engines of the *Maine* and of the *Texas* were forerunners of the passing of the horizontal engine for main propelling purposes on war vessels of our Navy. These engines were vertical, inverted, three-cylinder, triple-expansion engines, twin screw, having a piston speed of 800 feet per minute for the *Texas* with a steam pressure of 150 pounds at the engines. The piston speed and steam pressure of the *Maine* were 750 feet and 135 pounds. The *Cushing's* engines were twin-screw, five-cylinder, vertical, inverted, quadruple-expansion engines, a new departure for us, and twin screw; the boilers were of the old style dry-tube Thornycroft type, the first appearance in the American Navy of the small-tube express type of boiler for main power units in other than launches. The *Cushing* marked a still further increase in piston speed and in steam pressure, the first having risen to 928 feet per minute, and the latter to 250 pounds per gauge.

Of the vessels ordered during the next year, 1887, the cruisers showed a great decrease in sail power over the *Newark*, which had been barque-rigged. The only advance in engineering that was made was in the case of a monitor, the *Monterey*, in which, for the first time in one of our comparatively high-powered vessels of any great fighting value a large proportion of the power was supplied by water-tube boilers. On this vessel two-thirds of the total power was supplied by water-tube boilers manufactured by the firm of Charles Ward, of Charleston, West Virginia. They were of the cylindrical multi-coil type, and while giving satisfactory results until 1903, when they were replaced with water-tube boilers of a later type, they possessed several objectionable features—they were difficult to keep clean, both exterior and interior of tubes; tube renewal was difficult; on account of cylindrical form, the floor space necessary for a given amount of grate was excessive. While these boilers were successful, sea-going men, both deck and engineers, are very conservative, and it was several years before the water-tube boiler succeeded in displacing the Scotch boiler in naval vessels, and it is now struggling very hard to take the place of its competitor in the merchant service.

In 1890 was made the first attempt to attain maximum economy in propulsion at low speeds by means of dividing the total power on each propeller shaft into two units. This was done in the case of the *New York*, now the *Rochester*. This vessel was the first of our armored cruisers of the true type, and was followed in 1893 by the *Brooklyn*, having a similar arrangement of engines.

Chilling and Case Hardening

THESE terms are applied to cast and malleable iron (or steel) goods respectively, the working results being the same, but the methods and effect on the two forms of metal being different, chilling causing the cast metal to hold the carbon in suspension in the "combined" state so far as the chilled surface is concerned, while case-hardening is produced by the metal absorbing carbon, and then being quickly quenched. Although not the same as case-hardening, the surface hardening of copper and other non-ferrous metals can be accomplished by surface alloying with tin or other suitable metal at certain crucial temperatures, and this acts as a hardening medium much as the carbon acts on iron and steel, although the metals do not assume a gaseous state during the process as in the case of carbon.

In making chilled castings, the molten metal is run into or against whole or part moulds of cast iron of some thickness which at once solidifies the metal without allowing time for its constituents to separate and assume various forms as in a sand mould, suitable mixtures of iron being used, as some irons are nonchillable. The depth of the chilled parts depends partly on the iron used and partly on the thickness of the chill in regard to the bulk of the casting, but up to roughly half-an-inch chill can readily be had under suitable conditions. In cases where the whole of the metal is chilled, it becomes brittle and for this reason makes it necessary to use specially selected iron, which, by its strength, will to some extent counteract the weakness which is a characteristic of all brittle irons, but where there is a sufficient thickness, the soft metal prevents loss of strength to any great extent, while in some cases a chilled casting may very well be stronger than one which is not chilled. Chilled surfaces stand wear well, and usually have to be ground to finish them, as a file is of no effect on the hard surface, but given a sufficient backing of soft metal, such surfaces are very durable.

In case-hardening the articles are finished as to size and form, except for a light grinding where extreme accuracy is necessary, and are then packed in flasks in the carbon producing material, which is usually some form of animal charcoal plus prussiate of potash, salt, or other chemical, which is presumed to assist in the absorption of the carbon. The flasks have covers thoroughly luted on to prevent the admission of air, and are gradually heated to from 750 deg. Cent. to roughly 800 deg. Cent., and held at that temperature for some hours. The exact temperature depends on the content and bulk of the metal, and is not constant for all things alike, but usually the variations are not great. When finished, the hardened pieces are dumped into cold water, and after being dried are finished off for use if the hardened casing is thick enough, or it may be necessary to again pack and heat them to increase the depth of the hard casing. As to the depth to which the metal is hardened, wear has to be considered, but as from a sixteenth to three thirty-seconds of an inch is as a rule ample, there is no advantage in deeper hardening, while in many cases less than the sixteenth of an inch gives all the wear required.

For thin work, heating to a full red and plunging in a hot solution of cyanide of potassium will give good results, more particularly if the heating and dipping is several times repeated; but this method of hardening usually causes the development of hair cracks, which [illegible] its effectiveness, and to some extent pro- [illegible] some conditions of [illegible] they become practically [illegible] are rather apt to affect the surface of the metal, [illegible] this in the hands of the most skilful operator.

The advantage of case-hardening is in its providing a very wearing surface—as in the case of a wheel axle —while still retaining the toughness of the general body of the metal, in this way providing a safeguard against shocks which fully hardened metal could not withstand, this being the objective aimed at in both chilling and case-hardening. The full effect of this method is well shown in some armor-plate, which will resist the penetration of shells under a certain weight and velocity, and yet not split up, although, probably, some effect is produced at the point of impact provided the striking blow is heavy enough, but in any case the plate is not ruined as in the case of the non-hardened surface.

In the case of surface hardened non-ferrous metals, the effect is somewhat the same as in the case-hardened iron or steel, while in some instances there is some tendency towards peeling if the metal is bent about much, but the process has advantages for some kinds of work. The metal to be treated is freed from oxide as far as possible, fluxed, and sufficiently heated from underneath, the hardening metal being melted on the upper surface and well rubbed in until it alloys with the metal to be hardened. Surplus metal is then wiped off and the treated object allowed to become cold, when it is finished in the most convenient way. Copper can be made so hard with tin that a file will scarcely touch it, while other things can be made surface hard, aluminum possibly being an exception, as under heat it does not behave like other commercial metals, although phosphorus eases the situation to some extent. Provided someone would produce an easy method of surface-hardening aluminum, however, and that without sensibly increasing its weight, the thing would be of much value if only imparting rigidity, but it is not required for more than surface-hardening, and not general alloying purposes.—*The Practical Engineer.*

Collecting Barbed Wire by Machine

AMONG the novelties produced by the war is a machine for collecting barbed wire scrap in war-destroyed areas. The machine, which has a remote resemblance to a straw and hay elevator, is carried on caterpillar chain tracks. The wire scrap is picked up and cut into lengths, and then dumped into cars or pressed into bales.

Fig. 1. "Crack" produced on a glass vessel by a sharp shock, 3 diam. Note the symmetry of the surfaces originated and the tangency of these surfaces at their starting point.

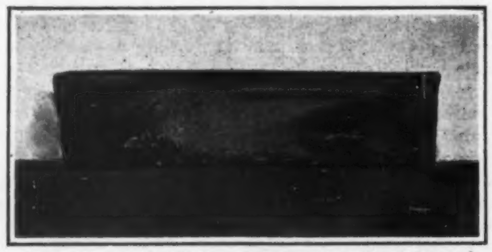


Fig. 3. A standard "Fracture Surface" in a glass slab 20 m/m thick. The schema shows the main characteristics of the surface.

Fig. 4. A standard fracture in Judea Bitumen, 3 diam. Note the surfaces overlapping each other and spreading on each other, as shown on the schema.

Fig. 2. Fracture of a thin sheet of glass, 1 diam. Note the great symmetry. All the network is originating from the splintering focus.

How Things Break—I

A Study of the Mechanism of Fractures in Materials

By Charles Freminville

WHEN a piece of machinery happens to break, it is of the highest interest for the engineer to know why it broke. A good many people will immediately say: "It broke because the material was defective in some manner." And as they know a thousand ways for material to be defective, they are very prompt in assigning at least one of them to each particular failure, and rest satisfied. To some people the question is not so easily answered, hence the numerous researches and laboratory tests by placing material under conditions similar to those met in actual practice: tensile, impact and shearing tests, alternate tension and stress tests, scleroscope tests, Brinnell ball tests, etc. All these tests are very useful for enabling us to identify a certain quality of steel known as giving good results in practice; but as they cannot pretend to place material under anything like practice conditions, no more than to give a correct measurement of any clearly specified property of the matter, they require a good deal of interpretation and still leave a good deal of uncertainty on what is going to be the behavior of a new material under practice conditions. It often happens also that they do not enable us to find the cause of certain ruptures, therefore it may be said that the experimental part of the Science of Strength of Material still offers a large field for investigation.

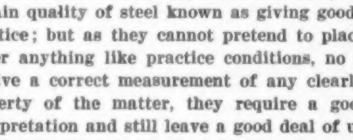


Fig. 4a

As a contribution to the subject, the author has undertaken a study of the fractures themselves to find out how material breaks with the hope that knowing "how," he may be on the way of knowing "why." Whatever may be the result, he thinks that the curious facts met in so common an occurrence as a fracture, and which seem to have failed to attract attention up to the present time, are worth a moment's serious consideration.

The following researches originated with the inspection of pieces of steel broken in actual service, and of test pieces broken under known conditions; but it was soon discovered that the fractures of all sorts of materials had common features which were more distinctly seen in compact and brittle material, such as glass and Judea Bitumen, and therefore particular attention was given to the fractures of the last named materials.

If a slab of glass is broken by a heavy blow struck near its center, or by a heavy pressure applied to the same point, the result is usually a complicated fracture dividing the slab into a great number of pieces. (Figs. 1, 2 and 3.) This first fact of "multipartition" is worth noting, for the production of numerous fragments of various dimensions down to splinters or crumbles, cannot be traced directly to the stress originated by the blow or the pressure, and calls for explanation.

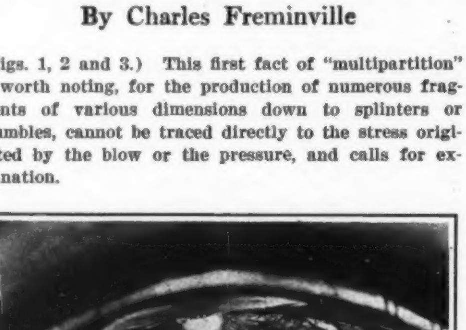


Fig. 5. Small splintering focus, followed by important splintering; glass 13 diam. Note symmetry in converging rays, "fan surfaces", etc.

Fig. 6. Another splintering focus; glass 2, 5 diam.

In addition to these surfaces dividing the slab into a great number of pieces, the fracture will also develop several surfaces sinking more or less deeply into the slab without cutting off a fragment.

The great symmetry in the general disposition of the surfaces limiting the fragments, as well as of the surfaces partially cutting the slab, which is most remarkable as seen in the photographs, is also a very important fact which can no more be attributed to the direct action of the stress caused by the blow or the pressure starting the fracture.

While we are considering the general disposition of the fracture we might as well note that these surfaces above mentioned, which are only partially developed, and may be seen through the mass of the glass, have no contact with the outer surfaces of the slab, at least on a very important portion of their furthermost extension, and are distinctly progressive through the mass.

A first inspection of the "fracture surfaces" of the fragments of the slab leads to the detection of a place of very striking appearance, of which we give several photographs. This part of the surface, located in the neighborhood of the face of the slab opposite to the one on which the blow has been struck, or the pressure applied, attracts the attention as a bright spot, circular or elliptical, of a few square millimeters (sometimes larger) surrounded by a dull edge. More or less important rays converging towards that surface render it very easy to be found.

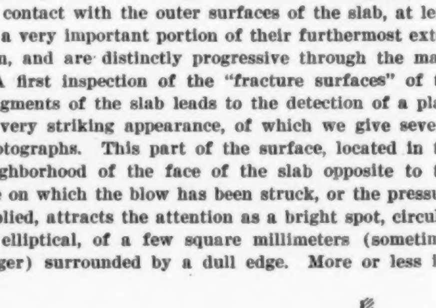


Fig. 4b

Having found that small surface (Figs. 4 and 6), if we put together again the different pieces of the broken slab, we see that all the surfaces of the fracture originated from that particular surface, to which they can be considered as tangential (the fracture surfaces which do not come into contact with that focus are "branches" of the first ones). This would be enough to infer that this surface had a very important rôle in the development of the fracture, and, henceforth, we shall call it the "Splintering Focus."

If we undertake now to study one of the main surfaces of the fracture (Fig. 5), and if for that purpose we choose a surface which is not too complicated, we have before us a very regular arrangement. We first notice bright spaces of rather large dimensions, more or less undulated, and dull spots of less importance. Then we note that the smooth surfaces are slightly incurved in a spoon-like fashion, the middle line of the incurvation passing through the Splintering Focus; that the dull spots form rays and that these rays originate from the same focus. Again we find, on these

Fig. 7. Surface fracture in Judea Bitumen. Note the fanblade like surfaces overlapping each other at different stages, etc.

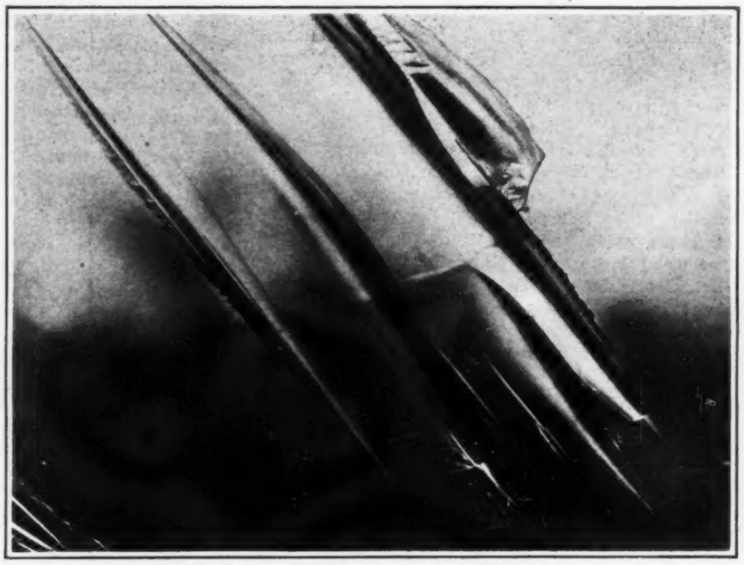


Fig. 9. Elementary splintering clusters, glass 15 diam.

surfaces, rays looking like sharp grooves, and these also spring from the small surface of the splintering focus. These facts strengthen us in the opinion that the main surfaces of the fracture have originated from outside of the splintering focus.

Carefully observing one of the grooved rays found on the fracture surface, we meet with most unexpected and interesting facts. The ray is produced by the junction of two surfaces, looking very much like the blades of a fan overlapping each other. Each of these surfaces bears witness that it has gone through three different stages α, β, γ in deveolping. (Fig. 4a.)

α is the fan blade proper, whereas β and γ belong to the connection between two adjoining surfaces. In the stage α the two surfaces are practically straight and running parallel; in the stage β they become incurved all around towards the neighboring surface α; the stage γ begins in the close vicinity of the neighboring surface α. The surface γ is then running in a somewhat parallel direction to the said surface α and becomes nicely covered with ripples. This surface γ is usually asymptotical to the neighboring surface α but does not join it. The thin space between surfaces α and γ is finally broken in an irregular way but through another process.

In these three stages, the elementary surface of the fracture resembles strikingly the surface of a sheet of water running in a gutter (α); passing over a dam, and then expanding in a shallow pond (γ).

If we bring a bright light to reflect on surfaces α, we see on these surfaces very small undulations or ripples belonging to two distinct systems crossing each other at a pretty constant angle. These ripples are very similar to those seen on the surface of the water running in a gutter, above alluded to. The ripples seen on the surfaces γ are quite different, they are larger and run parallel but do not cross each other.

That similarity between the surface of a fracture and the surface of running water is very striking, but as we do not wish to be tempted into theoretical considerations, however inviting the circumstances. We only record that curious analogy, and we maintain that α surfaces have developed first, since β surfaces came towards them and γ surfaces are practically expanded on them; and as we meet with the same processes on each of the two α surfaces, we can say that these two surfaces have developed simultaneously.

The junction of two surfaces α that we have just described is more than an accident in the production of a fracture surface, and a close inspection of the main surface shows that rays of smaller importance are met all over large spaces which are made of a great number of narrow surfaces overlapping each other. (Figs. 7 and 8.) This fact is very important as throwing a new light on the production of fractures. The first idea coming to the mind as to the development of a fracture would be that the surface is growing along parallel lines enveloping each other as produced by a flowing tide. This can no longer be admitted. The advance of the surface is due to narrow surfaces shooting forth and extending into the mass, overlapping each other, and connected one with the other as is shown above. (Fig. 9.)

[TO BE CONTINUED]

Bacteriology of the "Spanish Influenza"

The pandemic of influenza has not spared any single part of Germany. The clinical course does not seem to differ from that run by the disease in this country. Relapses and fatal pneumonias are particularly noted. The clinical picture is declared to be identical with that of the last pandemic of 1889. A very striking observation has been brought forward and generally confirmed at a special meeting of the Munich Medical Union on July 9th—namely, that persons under 30 years of age mainly fall victims to the disease; this was explained by a survival immunity in the elder generation. The meeting considered all the aspects of the epidemic on the basis of the hospital and University material of Munich. Pfeiffer's bacillus has been found but exceptionally; streptococci, and occasionally

Fig. 8. Fracture surfaces developing from splintering focus, 15 diam. Note the overlapping and the three stages; note the ripples crossing each other; dull rays; fracture surface turning into a new splintering focus, etc.

pneumococci, were recovered from the sputum, organs, and also blood of the patients. Similar findings were recorded in 1889, and thus the present results were in "keeping with precedent." Pfeiffer's bacillus had not been found in 1892, although it should have been impossible to overlook it in 1889, thus it may be that it will yet turn up in due course. The editors of the *Deutsche medizinische Wochenschrift* have addressed a circular inquiry to all the leading bacteriologists in Germany requesting enlightenment as to the results of their laboratory investigations. Pfeiffer himself had reserved his final opinion as to the relationship of the pandemic with those of 1889 and 1891–2. He had not examined a sufficient number of cases at Breslau, but found his bacillus in some while failing to recover it from others, and was still investigating the causes of this discrepancy. Gruber answered from Munich very simply: "Influenza bacilli not found hitherto—investigations proceeding." Ulrich Friedemann, who is in charge of the infectious wards of the Virchow Hospital of Berlin, expressed his belief that the symptomatology and complications of the epidemic correspond exactly with those described in 1889–90. He had not found the Pfeiffer's bacillus, streptocci and pneumococci being the most common agents of the complicating penumonias. The influenza bacillus may be evading capture on account of faulty method of inquiry, yet on the other hand the possibility must not be overlooked that there may be epidemic diseases clinically resembling influenza of which the Pfeiffer's bacillus is not the agent. Uhlenhuth has so far reported from Strassburg the same contradictory results as those of Pfeiffer. Kolle reported under the date of July 18th from Frankfort his failure to detect Pfeiffer's bacilli in any of the few cases which he had thoroughly examined. In practically all cases there were found, however, large numbers of a Gram-positive coccus—often in a pure culture or in symbiosis with pneumococci. The diplococcus tended to develop involution forms and to grow in very long chains in the condensation water. He regards them as agents of a secondary infection in the "Spanish disease" which to his mind may not be identical with the pandemic influenza of 1889–1893. The finding of this pleomorph Gram-positive diplococcus is very interesting in view of the observations of Rosenow and his pupils in the United States.—*The Lancet.*

Mechanism of Development of the Image in a Dry Plate Negative

A description is given of the appearance of cross-sections of developed film over a very wide range of exposure. If a film is exposed until a visible image is formed, so that reversal would show on development, and is then fixed without development, a red image is left which has the appearance under the microscope of shells of light-reduced silver. It is suggested that these shells, probably along with surrounding films of gelatin halide, act as protective coverings for the silver halide grains and so retard development. The inertia of a plate is found to vary according to the development it receives, being a maximum at about γ=0.8. In an example given the inertia was 0.22 at γ=0.295, time of development =¾ min., 0.19 at γ=0.8, time=2 mins., and 0.36 at γ=2.7, time=12 mins.; taking γ=0.8 to γ=1.4 as the range of normally useful development factors, the variation of the inertia value from the value at γ=1 is on the average —13 per cent on one side and +26 per cent on the other. Constancy of inertia over a fairly wide range of γ values was found generally only with an easy tendency to fog. The author has observed that low densities develop to their maximum more quickly than high densities, and it is suggested that the change of inertia may be due to this. The variation of plate curves with strength of developer was also examined and a developer half the strength of that originally recommended by Hurter and Driffield was found to give a longer straight line portion in the curve and a lower inertia than either stronger or weaker developers. The addition of increasing quantities of bromide to the developer was found to give an increasingly lower rate of development, higher inertia, and somewhat longer range.—*Note in J. Soc. Chem. Ind. on an article by F. W. T. Krohn in Phot. J.*

X-Rays and the War*

It was close on two years before the first formal meeting of the Röntgen Society, just twenty years ago, that Röntgen had stumbled, so to speak, across a new type of radiation, the wonderful properties of which excited the whole civilized world.

Since then the art of radiography has gradually extended into fields one never dreamt of. A present-day development, very typical of the times, is the detection of contraband metals, the examination of autogenous welds, and the scrutinizing of steel and other metal castings and plates for faults and blow-holes. Such work demands high voltages and the heaviest outputs. Already steel plates more than 1 in. thick have been successfully examined.

But the all-important use of the X-rays is their medical application. Every hospital of any size now has its X-ray department, and there are many thousands of radiologists—both medical and laymen—devoting their lives to the work. X-ray technique has improved so vastly as to give the diagnostic methods of physician and surgeon a facility and exactitude never deemed possible at one time.

In the large military hospitals the great majority of wounded soldiers are X-rayed. The examination of wounds and injuries by X-rays has, in fact, become routine practice, whether in the field, by the use of the ingenious and cleverly designed motor-lorry outfits, or in the base hospitals. The X-ray has become as indispensable as the dressing or the splint, and it is an essential adjunct in prescribing and directing, as well as avoiding operations. Even sprains are radiographed to find whether there is any slight bone fracture—as there very often is.

The X-ray detection of embedded bullet and shell fragments is now so certain as to be commonplace. Bullets and shrapnel are found and removed from any part of the body, even from the lung and brain or in the region of the heart. Precise instruments for localization in the actual operating theatre are now in use, and even during the operation itself the surgeon's instrument may be guided to the foreign body. Stereoscopic fluoroscopy is possible, and if a practical apparatus could be produced it would be of incalculable value to the surgeon and radiologist in their combined efforts.

Unless there is a suspicion of septic poisoning a bullet is generally best left alone, but shell fragments are usually dirty, and the nature of the damage they inflict along their course makes it important that their exact position should be known. It is in such cases that X-ray stereoscopy attains its fullest delicacy. For example, the location of small foreign bodies near the eye, or actually in the eyeball, can be carried out to the hundredth of an inch.

In the case of a fracture, the stereoscopic radiograph reveals the direction of the fracture and the disposition of the broken bone, and so assists the surgeon in deciding on the method of reparation. After the bone has been set, the progress of the recovery can be clearly followed in the subsequent photographs—whether the parts are joining up, whether new material is forming. The sequence of radiographs is included in the record of each case. The total number of photographs already taken at the various hospitals since the war commenced amount to many hundreds of thousands. Very valuable data will be obtained when time allows the radiologist to go carefully over all the accumulated records of cases.

The value of the X-rays in diagnosing chest complaints has been established again and again in this war. This is the case particularly with incipient tuberculosis, where early diagnosis is of great importance. Not only the diagnosis, but the treatment of tubercular glands has been attended with considerable success. Great attention has been paid in this war to the soldier's teeth, and very rightly. Here, again, the X-rays are playing their part and dental radiology has become an important subject. No more than mention can be made of the splendid work of "opacity" radiology, which can diagnose with routine certainty diseases of all parts of the alimentary canal. This has been of great service in examining Army recruits of doubtful medical fitness.

A word should be said as to the invaluable results obtained from single-flash exposures, especially in heart and lung conditions. Another war development of radiology is its employment by the orthopædic surgeon in his efforts to restore damaged limbs.

But the beneficent effects of the X-rays do not end with radiography. They have achieved wonderful results, not only in the diagnosis, but also in the repair of wounds. Amongst the minor tragedies of the war, few are more pathetic than the ghastly mutilations and disfigurements caused by shell wounds of the face and head. Many of our soldiers would seem to be doomed to a life of perpetual misery and humiliation, but by the wonderful plastic operations of the surgeon they can be restored to at least a semblance of their former selves. The radiologist's part in such work is to render scar-tissues pliant, to depilate hair from the scalp and skin surfaces concerned, to render the transferred flaps of skin pliant and more adaptable to their new positions, and to stimulate generally the healing process in both flaps and bone. For these purposes he employs radiation treatment, either X-rays or radium rays.

In the treatment of septic wounds and persistent sinuses, the most extraordinary success has resulted from a combination of X-rays and ultra-violet rays. Hyperthyroidism, or "soldier's heart," has been successfully treated by X-rays and radium rays.

The electro-therapeutist has also been prominent in war work. Countless electrical departments have been established in military hospitals throughout the country for the treatment of war injuries. Quite one-half, if not more, are gunshot wounds of the nerves with paralysis of the muscles. These cases are sent for electrical examination of the injured nerves and subsequent electrical treatment. Many cases of war wounds, more particularly those of the uncomplicated but inert type which refuse to heal, are treated electrically. Simple application of a direct current stimulates the process of repair, and sluggish wounds at once commence to heal. "Trench feet," which occurred in large numbers last winter, receive benefit by electrical treatment. Cases of shell-shock and neurasthenia and other functional disorders of the nervous system, some of which are seldom or never seen in times of peace, are now being cured in large numbers by electrical means.

And so the story goes on. The radiologist and the radio-therapeutist have found their reward in the gratitude of many men to whom they have once more made life endurable.

The outbreak of war found the X-ray manufacturers, like everybody else, quite unprepared. The greatest credit is due to them for the splendid way they threw themselves into the breach and turned out, in record time, unprecedented numbers of outfits for the Army. The X-ray bulb manufacturer was at once confronted with the absence of the glass, which Germany had hitherto supplied. The English glass manufacturer had to face the task of producing a uniformly good glass which would stand up, without puncturing, to the high voltages which obtain in practice. The problem was very difficult, but it is gradually being surmounted by State aid. In the meantime our American and French friends came to the rescue.

It is remarkable how slight have been the changes in design experienced by the target tube. He would be a bold man, nevertheless, who would assert that the present design has approached finality. All X-ray tubes are, in fact, extraordinarily inefficient things. Under favorable conditions they make use of rather less than one part in one thousand of the energy imparted to the cathode rays.

The Coolidge tube, first introduced nearly four years ago, has been considerably improved in detail, and now claims pride of place among X-ray tubes. It is not entirely free from defect, and its rays are no more homogeneous than those from an ordinary bulb, but its elasticity, precision, ease of control, long life, and relative freedom from inverse current make it an invaluable addition to the radiologist's equipment. Some wonderful output figures have been obtained by Coolidge on experimental water-cooled models. One tube was run continuously for many hours at 200 milliamperes and 70,000 volts, the power input being 14 kilowatts, *i. e.* about 19 h.p. It is anticipated that this figure will be shortly increased to 50 kilowatts.

It was hoped on its introduction that the Coolidge tube would be the means whereby X-rays approximating to the hardest γ rays from radium would be obtainable. Such anticipations have not been realized. In some recently published work Sir E. Rutherford describes measurements on the very hardest rays emitted by a Coolidge tube excited by close on 200,000 volts. In order to filter out the hardest rays present he passed them through 1 cm. of lead, the reduction in intensity being more than a millionfold. The residual rays proved to have a wave-length of about 0·06 A.U., which may be compared with Rutherford's latest estimate of the wave-length of the hardest γ rays from radium C—between 0·02 and 0·007 A.U. In other words, the Ra γ rays in question corresponded with X-rays generated by voltages between 600,000 and 2,000,000—figures to which no X-ray tube of present-day design could possibly stand up, even if we had the means to produce such voltages on a practical scale.

As to the composition of the X-rays generated by an X-ray bulb, we know now that the rays consist in general of two groups:—

(*a*) A continuous spectrum of rays with a sharply defined boundary on the side of the shorter wave-lengths, the position of such boundary depending on the voltage on the tube.

(*b*) One or more characteristic radiations (of the ...J, K, L, M,...series), each approximately homogeneous and characteristic of the metal of the anticathode. The higher the atomic weight the more penetrating the radiation in the same series.

The proportions of (*a*) and (*b*) depend entirely on the conditions. With very soft tubes a large proportion of the radiation may be wholly characteristic.

With reference to the spectrum of general rays, it has recently been shown that the maximum frequency of X-ray which a tube can yield can be readily calculated by a simple extension of Planck's quantum theory. The relation in question (due to Einstein) is $Ve = hv$, where V is the voltage on the tube, e the elementary charge on each cathode ray, v the frequency of the hardest X-ray produced, h is Planck's constant. e and h are known with considerable exactness, so that we have the means of calculating very readily the voltage necessary to generate a particular X-ray. Inserting Millikan's latest values of these constants, we have

$$\text{Wave-length in A.U.} = \frac{12{,}400}{\text{voltage}}.$$

The accuracy of this simple relation has been confirmed experimentally over a wide range of voltages in America. It will be noticed that the result is independent of the material of the anticathode.

With reference to the characteristic radiations, each consists of a number of spectral lines. For these, Einstein's simple law does not hold, a greater voltage being required. Webster noticed that the various spectral lines of a series all spring into being together as the voltage is increased through the critical value.

Through the medium of the X-rays we have unveiled a few of the secrets of the structure of the atom. The biggest development has resulted from the discovery of the wave-like character of the X-rays. It was Laue and his pupils in 1913 who first demonstrated the diffraction of X-rays by crystals, but it was in this country that the first real insight into the problem came. The Braggs showed how the crystal reflection of X-rays could be utilized to separate out different waves in a fashion exactly analogous to the production of interference colors by thin plates. The X-ray spectrometer revealed both the atomic spacings of a large number of crystals and the absolute wave-length of a variety of monochromatic X-rays.

The work of Moseley stands out pre-eminently here. Moseley photographed many characteristic X-ray spectra, and measured the wave-lengths of the principal lines. He was able at once to obtain the very remarkable and simple relation now associated with his name, namely, that the frequency of a characteristic X-ray from any element is proportional to the square of the atomic number of the element. This atomic number must be distinguished from the atomic weight. It denotes merely the order in which the elements come when arranged according to their atomic weights. Thus the atomic number of hydrogen is 1, of helium 2, of lithium 3, and so on. The atomic numbers follow the order of atomic weights except in three instances: argon and potassium, cobalt and nickel, iodine and tellurium are interchanged.

The X-ray spectra are revealed as an extreme type of light-ray spectra, and are even more characteristic of the parent atom. Later work has shown that X-ray spectra contain many lines and are much more complicated than was first believed.

Moseley's work has been extended by others, notably by Siegbahn and Friman. We now know the atomic numbers of all the known elements, beginning with hydrogen and ending with uranium—with an atomic number of 92. Each of the atomic numbers is represented by an element, with the exception of numbers 43, 61, 75, 85, and 87, which stand for five elements waiting to be discovered. It by no means follows, however, that there are only five missing elements; five is a lower limit, for we now know that several elements may have the same atomic number. Such isotopes, as Soddy has called them, cannot be distinguished one from another by ordinary chemical or

*Abridged from the Presidential Address delivered to the Röntgen Society by Capt. G. W. C. Kaye. Reproduced from *Nature*.

physical tests. They are grouped together under the one atomic number in the periodic classification of the elements, but, nevertheless, they may, and do, possess atomic weights differing by several units. It is apparent that the atomic number is something more than a mere integer; it undoubtedly represents some fundamental attribute of the atom, and as the work of Rutherford and others has shown, the atomic number equals the excess number of positive charges in the nucleus of the atom.

The boundaries of the known spectrum have been considerably extended since the war broke out. In the ultra-violet Lyman has extended the region first investigated by Schumann to a wave-length of about 500 Angström units, and Richardson and Bazzoni have very recently further extended this to 420 A.U. The longest X-ray so far measured by Siegbahn has a wave-length of 12 A.U. Rutherford has recently given evidence for believing that the wave-length of the hardest γ rays from Ra-C is in the region of 1/100 A.U. We are thus now familiar with a range of more than ten octaves of X- and γ rays without a break—not at all a bad record for so young a subject. There still remain about five octaves to be explored in the region between X- and ultra-violet rays, a region which contains the characteristic X-rays of the light elements from hydrogen to neon.

And now to turn to quite a different topic. At the moment we are all reproaching ourselves for our past neglect of science in this country. We are paying the penalty of our indifference, despite the wonderful adaptability and resource which this war has shown we possess as a nation. The country is slowly learning its lesson. Willy-nilly, we are being led to see at last that our system of education misdirects much genius into unproductive channels, and we are awakening to the importance of research, both pure and applied.

The value of applied science to industry is now accepted throughout the country, and British industry should begin to feel the benefit, especially now that the principle of State-aided research is established.

But we must not forget that it is the pure academic research, unrestricted and unprescribed, which has been the prime cause of all the radical changes in industrial methods. Research in pure science is rarely appreciated by the general public or manufacturer, for it cannot be done to order. One must put faith in the research worker that he may continue to have faith in himself. Much of what he will do will be discontinuous and abortive, but he must not be hampered by utilitarian notions being continually rammed down his throat. If he does not solve the original problem he will probably solve some other which has sprung from it, and one successful discovery may outweigh by far all his failures.

The equal importance of the applied research worker, who is responsible for turning to account the discoveries of the pure investigator, must not be lost sight of for a moment. There is no line of demarcation between the two divisions of research. Each involves study, hard work, and thought. The methods of both branches are questioning and searching; the common end is knowledge, to which there is no heaven-sent road.

What has been the reward of the research worker in the past? It is the shameful truth that the man of science, with few exceptions, has received little or no recognition by the mass of the people of this country, who, unknowing and uncaring, have been perfectly content to allow him the status, both social and financial, which he himself has modestly sought for his everyday life and wants. But the country, in its hour of need, has turned to its scientific sons for help in its war problems, and has not turned in vain. The war is bringing home to the nation the dependence of its very existence on science, and a little good may come out of a very great evil if public opinion can be brought to realize that the statement is as true in peace as in war, and that a nation's administrators should always include among them suitable men of the highest technical and scientific standing, not merely to advise, but also to initiate and direct.

Winged Victory

For real thrills and strenuous action of the most varied character the air service undoubtedly transcends all others, as may be gathered from the following incidents collected by *Aeronautics* of the doings of British airmen:

Since the early spring we have had a pronounced and uninterrupted superiority over the enemy in the air which has grown more conspicuous week by week. Never has it been more indisputable than during this last spell of fine weather. One of our famous airmen has shot down 25 German machines in the course of a single month, bringing his total victories up to 75; and we have others with over 50 victories to their credit.

Air fighting, however, is only one manifestation and symptom of what is going on. The real thing that counts is that the mastery obtained by our fighters enables the Air Force as a whole to carry on its great work of observation and photography and general co-operation with other branches of the Army. It is the volume and quality of this work which makes it possible for our artillery to do immense damage to enemy troops and guns.

Our bombing, also, is superior to the enemy's. Not only are the number of machines employed in this work, the number of raids made, and the number of bombs dropped much greater than the German, but, besides doing a great proportion of our bombing by day instead of at night, like the enemy, we constantly now drop our bombs from heights of only a few hundred feet, or even less than a hundred, while the Germans, with rare exceptions, keep to something like 10,000 ft. The difference in accuracy of aim and magnitude of results is obvious. Practically all the air-fighting has for a long time been well east of the lines and over enemy territory, but beyond this zone of fighting our bombers almost daily push farther and farther and our low-flying machines, with bombs and machine-guns, harass the enemy farther and farther back.

In the recent Australian fighting our airmen found divers new ways of making themselves useful during battle and helping to contribute to victory, and it is far from being in air combats alone that they show initiative and inventive resource.

On the same day as the battle a patrol of ours well beyond the lines fell in with a party of 20 Germans, whom they attacked. They out-manœuvred and out-fought them, destroying four before the rest got away, and all our machines came home unhurt. Three days before that four of our machines got mixed up with 40 Germans in the Proyart area, and one of our pilots, whom we will call Captain X, that day had a busy time. He was out alone, when he met an enemy fighting machine, attacked it, got over its tail, and sent it down in flames. A little later he met another isolated enemy. He attacked again, and, after a short burst, the German went vertically, nose first, to earth. Then it was that he joined up with the patrol of three of our machines, and the four together got entangled with the 40.

Captain X singled out an Albatross scout and shot its wings off in the air. Then, turning his attention to another enemy, he dived on it from above and sent it down out of control. By this time he had lost touch with his recent companions, and, having downed four Germans, thought he would count it as a day's work, and started home. But a patrol of four enemy scouts, probably part of the original 40, saw him, and gave chase. When they were close behind him "X" side-looped up over the leader, and, getting above him over his tail, shot him down in flames. The three drew off, and as "X" had now used up all his ammunition, he came home.

The experiences of our airmen are full of this sort of thing. One of them was recently attacked by three enemies, who were in such a hurry to eat him up that two of them came into collision. The wings of one broke off, and it went down like a stone, while the other started downwards in a slow spiral. Our man went after it, and when he fired into it, it broke into flames and crashed. On July 6, one of our patrols was out at a height of 10,000 ft. and saw six enemy scouts, but itself had not been seen. We attacked, our patrol leader picking out the third enemy machine, which went down vertically, to crash helplessly below. Our man then attacked the second in the line and shot that down, and in falling the enemy hit the German leader, and both went to earth together in one jumbled mass. The other three enemies got away, but just then a German two-seater came along, and again our patrol leader attacked and sent it down. By this time he was really feeling like fighting, and when he caught sight of three enemy machines together he went for them; but they would have none of it, and he chased them for three miles fruitlessly before giving up and coming back to collect his patrol and bring them home.

And these things are only, as has been said, one detail, almost an incidental detail, of the real work of the Royal Air Force.

The following published in the daily Press, is the first descriptive account of one of the bombing raids into Germany, which have become a matter of almost daily occurrence since the recently formed Independent Force of the Royal Air Force began its activities:

"Back on the green aerodrome, miles behind the lines, the big British bombers were prepared for their raid. Rows of huge machines stood waiting for the finishing touches, looking, in the twilight, like giant birds roosting on the ground. To one side were the smaller fighting aeroplanes which would escort the raiders on their long flight over German territory. Tanks had already been filled, and now the huge bombs were wheeled out on trollies and fitted to the underside of the planes; belts and drums of ammunition were placed ready for use, and the engines run up to see that all was in order.

"A little before dark the pilots and gunners arrived by twos and threes. Each officer carefully examined his particular part of the machine and one by one the aeroplanes left the ground in the gathering dusk and began at once to climb. Last of all the escorting machines went up.

"Mile after mile they flew through the darkness. Below, the faint outlines of fields and roads could be dimly distinguished, with ponds and streams gleaming through the night. They crossed the fighting lines at an immense altitude, untroubled by 'Archie' or any other terror of the sky, steadily humming toward the big German town which was that night's objective. After a good two hour's fight a signal flared from the leading machine. The Rhine was at hand, and every one prepared for action. Guns were fingered tenderly, bomb releases looked to, and sights adjusted.

"Then the first searchlight picked up the formation, and a moment latter the sky was covered with puffs of smoke; shrapnel shrieked through the air, and long, wavering beams flashed hither and thither to aid the German gunners at their task. Down went the noses of the machines as they dived through the barrage, each pilot intent on keeping his place in the formation and hoping that a stray shot might not reach his engine. The fighters remained on high, waiting for the German aeroplanes which would soon arrive out of the darkness.

"Another signal flashed out, and factories and railway station were now within easy range. One by one, and in salvoes, the pilots planted their bombs. Muffled roars from below announced the arrival of tons of high explosive; red flashes showed where the explosions took place. At one place a huge sheet of flame shot upwards, tinting half the heavens with a rosy glow. A moment later a louder boom showed the cause of the fire —the main object of the raid had been achieved: the munition factory hit and a conflagration started.

"Up to this point the work of the raiders had been simple. Then the German night pilots came on the scene, endeavoring to break up the formation and overpower the bombers singly, instead of attacking them when they were well able to defend themselves. This was precisely the chance which the escorting fighters had waited for. Diving through the night, they fell on their foes, shooting at close range, sending two of the Germans down in flames, to add to the terror of the town below. 'Archie,' meanwhile, had died away; there was as much danger of hitting friends as of bringing down foes in the wild turmoil which now filled the night.

"At last all the bombs were dropped. Several fires glowed in the town, and at least one terrific series of explosions proved that the heart of the target had been reached. The signal to retire was given, and the formation withdrew, whilst the escort acted as a rear-guard to drive off any foes who were venturesome enough to follow.

"Another terrific storm of shell fire greeted them as they left the town, but no damage was done, and the barrage gradually died down as the machines drew out of range. Westward flew the formation, each aeroplane maintaining its position in line. Overhead the stars glimmered, and nothing now disturbed the peace of the night except the roar of the powerful engines.

"When halfway home the leader descried another formation looming out of the darkness. He signalled to his flock to be on the alert, for he did not know whether it would prove to consist of friends or foes. The approaching machines drew closer, and were at last distinguished for bombers, like themselves, bound to the same town which had just suffered, but was to suffer again shortly."

Mercury Production

The world's annual production of mercury is about 4,000 metric tons, of which Spain contributes about 1,400 tons, Italy nearly 1,000 tons, Austria-Hungary 800 tons, and the United States about 750 tons. England's pre-war consumption was over 600 tons; of the 1,600 tons imported about 900 tons were shipped abroad.—*Chem.-Zeit.*

Luminous Rockets and Bombs*

Devices for Throwing Light on Hostile Operations

SCARCELY a night passes on the Western front that the sky is not lit up at one point or another by luminous rockets.

To ward off surprises, to regulate artillery or rifle fire, or for observation of the enemy, it was needful to find a means of lighting the landscape at a distance which would be sufficiently powerful yet always at hand when needed. For this purpose rockets are chiefly used; they are employed either merely for illumination or for giving signals by means of their variation in colors and in other characteristics.

We shall here describe the principal ones of these devices, particularly the latest German rockets deriving our information from specimens recently captured from the enemy.

The rocket represented in Fig. 1, the 1877 model, is composed of a hollow rubber ball inside of which is an illuminating substance. We will not here state the precise composition of this substance, but may remark that such a substance might be obtained, for example, by a mixture of powdered magnesium or aluminum with nitrate of barium and glue. The composition is set on fire by means of a tin ignition tube, which contains a fuse mixture with a basis of black powder primed with a piece of quick match wick[1]. This piece of candle-wick is lighted after the top of the tube has been removed at the moment of employment and the rocket is then thrown. This rocket or grenade burns from 75 to 100 seconds and illuminates a circle 20 metres in diameter.

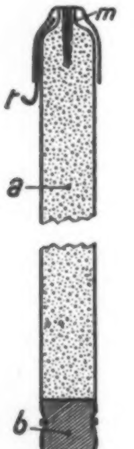


Fig. 2. Lamarre torch
a, Illuminating composition; *b*, wooden stopper; *m*, fuse; *t*, opening string

The Lamarre torch (Fig. 2) is composed of a cylindrical envelope of rubberized cloth filled with the illuminating composition; at the bottom there is a wooden plug and at the top is a fuse protected by a tin cap; the latter is lifted off by means of a specially arranged piece of string before the instrument is lighted. A torch of this kind 40 mm. in diameter lasts half an hour and suffices to illuminate the space occupied by two batteries.

The 1885 model signal rocket (Fig. 3) is composed of a shell-shaped carton loaded with a fusing composition and of a cylinder filled with devices each of which produces a star on bursting in the air; this arrangement is mounted on a stick of wood. This fusee is placed at the end of a rod about 1.8 metres long and leaned against a post; the fuse in the lower part is then ignited, the fusing composition takes fire and the whole thing is projected into the air. At the top of its trajectory, about 400 metres above the earth, the stars are shot out of the tube, which itself contains a little powder; at the same time the stars are ignited by this powder and produce lights of a color which varies according to their composition, each color having an agreed signification.

The self-acting rockets used to elevate luminous signals to a certain height have scarcely varied either in form or in constitution since the remote time when the Chinese made use of them to celebrate public festivals. The principle upon which they act is very simple; when the powder burns rapidly it produces a considerable quantity of hot gases which issue violently from the shell. A reaction results which tends to drive the shell in the direction opposite to the flow of gas. The action is similar to that in hydraulic tourniquet or reaction turbine.

The elementary explanation of such apparatus is well known; in a receptacle filled with a liquid the hydrostatic resultant pressure upon the lateral walls is nil. If, however, there exists an orifice of exit the force corresponding to the pressure which is exercised upon the surface of the wall thus suppressed no longer exists; consequently the resultant of the forces of pressure ceases to be nil: it is equal and directly opposite to the force of pressure which has been suppressed. It is to our advantage therefore, in the case in hand, to have a large surface in the opening and also a great interior pressure in order that the force of propulsion may be as great as possible.

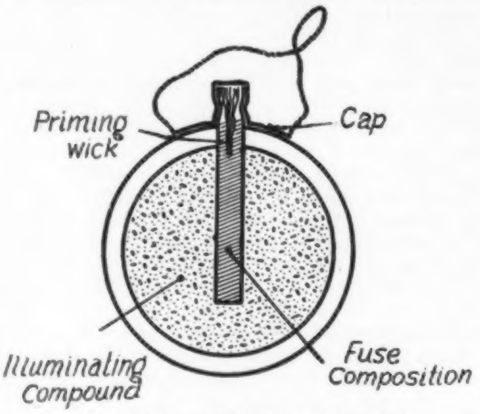


Fig. 1. Illuminating bomb, 1877 model

But these two conditions are evidently contradictory, and a compromise is necessary; the section of the exit orifice is determined in such a way that the pressure in the interior of the shell may be as high as possible without causing the action of combustion of the charge of powder to pass into the explosive stage.

Recently the use on a large scale of this method of propulsion has been considered, especially in aviation. Many specialists indeed regard the self-starting rocket as the projectile of the future. It is the only one in fact which contains its force of propulsion within itself, and this force is independent of external circumstances. It requires no gun to project it; in space the automotor fusee continues to progress since it is not supported by the atmosphere; and if ever any projectile—a peaceful one, let us hope—is shot at the moon, thus realizing the dream of Cyrano de Bergerac, it will doubtless not be a shell launched by some gun even more colossal than that to which the fury of the Boches gave birth, but some huge automotor rocket.

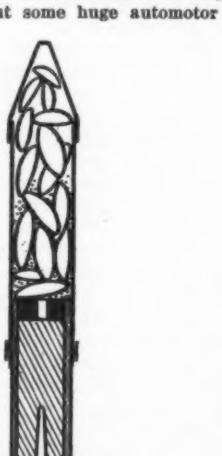


Fig. 3. Signal rocket, 1885 model

But this rocket will certainly not be so rudimentary as those which we now make use of; and this suggests a few words, not in regard to the improvements already accomplished though these are very important, but to the problems which remain to be solved.

Taking into account the results obtained in the steam turbine it will be necessary to provide the rocket with pipes of suitable size having a variable or non-variable orifice so as to facilitate the outflow of the gases and thus increase the efficiency of the apparatus. The generator of the gas, a species of powder, must have such a composition as will produce the maximum amount of gas at very high temperatures and pressures for a minimum weight.

That is to say, that black powder, more than one-third of whose weight yields solid combustion products, is far from being perfect; the colloidal powders, the explosives of the cheddite genus, are therefore all indicated; but unhappily as soon as the internal pressure in the shell is increased the action of combustion may pass suddenly into that of explosion. Finally, the form itself of the engine would benefit greatly by being designed with consideration for the information that has been gained from investigations with reference to the resistance of the air and the best forms of penetration.

Furthermore, the Marine Service employs under the name of Coston Lights devices analogous to the Lamarre torch, but made up of fuse compositions of various colors superposed (Fig. 4), whose succession corresponds to various signals by manœuvre.

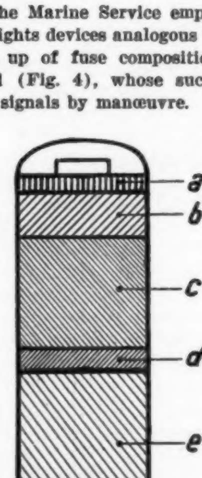


Fig. 4. Coston light
a, Priming pellet; *b*, composition giving a green flame; *c*, red; *d*, blue; *e*, white

The production of clouds of smoke which at present constitute one of the means of protecting merchant ships against submarines had been considered before the war, though for other ends, it is true. The object particularly in mind was to produce certain signals visible in broad daylight. Smoke can be very rapidly produced by means of various mixtures which undergo incomplete combustion. This combustion takes place either in the open air or under pressure, as the case may be. Let us cite for example a black powder (charcoal, sulphur, and saltpetre) in which the powdered charcoal constitutes a much larger proportion than in the ordinary explosive mixture or an aluminothermic mixture containing powdered aluminum, potassium nitrate and lead oxide in excess.

Fig. 5 shows the 1888 model of a smoke cylinder in section. It is a shell shaped carton filled with the smoke forming composition, ignited by a fuse tube of lead which is itself lighted by a piece of quick match wick.

The device is closed by two wooden disks, the upper disk being pierced by holes for igniting it and for the discharge of the smoke. One of these instruments burns for about half an hour. Combustion under pressure may also be employed, making use of a mixture of potassium nitrate, sulphur, and realgar (sulphide of arsenic), in equal parts; this gives an abundant amount of yellow smoke. In similar manner we may obtain smokes colored red, blue, black, etc. The general principle on which they operate is as follows: a combustible mixture is burned which is characterized by the liberation of comparatively little heat, and particularly by its burning rather slowly. In this mixture there is incorporated some substance which will form the colored smoke and this substance must

*From *La Nature*.
[1]The quick match is a cotton cord impregnated with "pulverin" (very fine black powder).

be readily sublimable. Under these conditions the combustion of the heating body will cause the coloring body (iodine, napthalid, the colors derived from phtalein, etc.) will be sublimed, *i. e.*, it will pass directly from the solid state into the gaseous state, giving off a colored vapor.

To produce clouds and volumes of smoke of considerable size, we have recourse to other artifices. The phenomena involved in the hydration of certain substances by the humidity of the air are often utilized. These substances include anhydrous chlorides of titanium or of tin (liquid of Libavius), oleum (sulphuric anhydride), or chemical reactions such as those of sulphuric chlorhydrine upon chloride of lime, (the smoke boxes of the Marine Service).

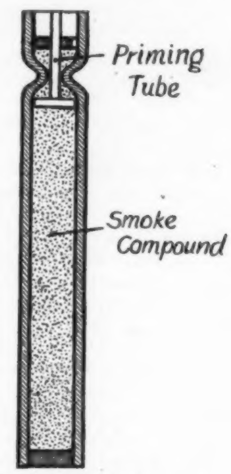


Fig. 5. Smoke cylinder

Other devices have been invented for the sake of carrying out certain ruses of war. Such are those designed either to produce the noise of a gun shot or to stimulate its flash, so as to deceive the enemy as to the position of the batteries. The "glowing chestnut" is composed of a simple shell containing powder to which has been added a slight amount of pulverized aluminum. This metal produces in burning not only a very high temperature but a very brilliant light.

We may also describe among the French devices long in use, the railroad alarm torpedo, which is frequently employed even in times of peace. This is composed of an oval shaped envelope of parchment cardboard, containing about 10 grams of a fulminating composition in which are embedded some glass beads. The composition, several varieties of which are imaginable, may be composed, for example, of a mixture of potassium chlorate and sulphide of animony.

This device (Fig. 6) is mounted on a small plate of tin which carries on its lower side a leaf spring designed to attach it to the rail. When the locomotive passes over the torpedo it crushes the glass balls and the friction of their fragments suffices to cause an explosion of the surrounding composition.

The artifices of which the greatest use is being made at present, the illuminating fuses and signals, have been modified from the regular old types in such manner as to make them easier and more rapid to handle. Signal lights have been constructed in the form of shells designed to be fired from special kinds of pistols or guns. Fig. 7 gives the section of one of these shells. The projectile driven by the powder *a* is a cylinder *b*, itself operating like a new shell: at its base is placed a charge of special powder *c*, which projects from the cylinder the flaming elements *d*. Each of these gives birth to a star, the number and color of which indicate the meaning of the signal.

The new illuminating fuses, both French and German are provided with a parachute. A section of such a shell is shown in Fig. 8. As we see this device is composed of a first shell *a*, which contains a second shell *b*, considerably longer. When the shell *a* is fired, by means of a special kind of pistol or rifle, the fusee proper *b* is projected into the air and at the same time the fuse *c* is lighted. The latter communicates fire to the charge of powder *d*, which, at the top of the trajectory, projects the cylinder *e* out of the tube *b*. This cylinder contains the illuminating composition to which the fire is conducted by the fuse *f*. The cylinder *e*, therefore, falls, shedding light, but it is sustained by the parachute *g*, which unfolds during the descent and retards it.

A series of 5 or 6 small tubes containing the illuminating stuff may also be strung along a cord several metres long attached to the parachute. Within the shell *e* these tubes are combined into a bundle, and

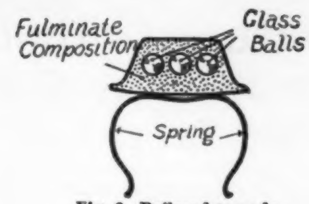


Fig. 6. Railroad torpedo

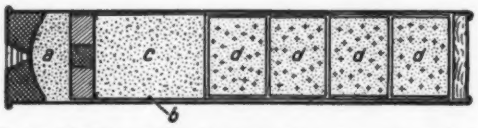


Fig. 7. Signal cartridge showing various successive colors

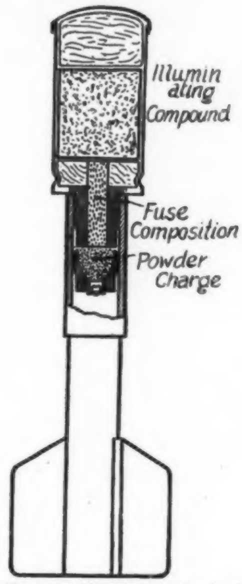


Fig. 9. A German illuminating projectile

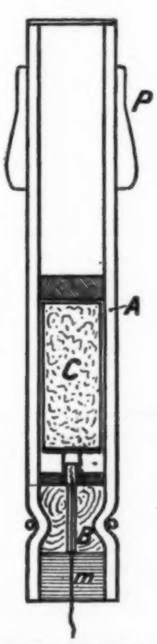


Fig. 10. An emergency signal tube

a, Cardboard tube; *p*, wire handle for carrying; *c*, illuminating cartridge that is ignited by the fuse *m*, passing through the wooden breech plug *b*

when they are shot into the air the cord unrolls and forms a slowly descending undulating "caterpillar."

One of the luminous devices most employed by the Germans is the feathered luminous grenade or rocket shown in Fig. 9. This is projected by the aid of a special rifle constituted mainly by a rod upon which is slipped the tube at the base of the grenade, and which forms a central firing pin. The action of this pin or hammer upon the percussion cap of the rocket ignites the charge of powder and produces the propulsion of the device. At the same time the mass of the illuminating matter is ignited through the central channel. The total length of the device is about 0.3 m.

It may be added that an analogous device might serve to carry messages and has often been used for this purpose by the enemy, to permit his units of the first line to communicate with the rear when the telephone lines were interrupted. For this purpose the rocket proper contains no illuminating compound, is closed hermetically at the bottom, and furnished with a removable stopper at the top.

Fig. 10, finally, shows a rudimentary device which has been much employed by the enemy. It is a tube of strong cardboard *a*, about 0.3 m. long, provided with a

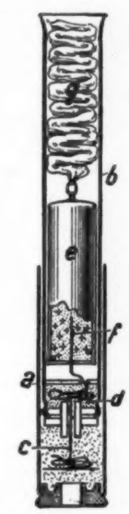


Fig. 8. A parachute rocket

a, Shell of projecting cartridge; *b*, fusee case; *c*, fuse for igniting powder charge, *d*; *d*, powder for projecting fusee, *e*, and parachute, *g*; *e*, carton containing illuminating, or colored signal compound; *f*, fuse for igniting *e*; *g*, parachute that expands when released from *b*

handle *p* at the top and arranged like a gun. At the rear is a wooden breech *b*, through which passes a fuse *m*, which, when lighted, sets fire to a charge of powder; this then projects the rocket proper *c*, setting it on fire by its lower aperture.

Utilization of Rotten Potatoes in the Manufacture of Starch

Spoiled potatoes are suitable for starch manufacture provided decomposition has not gone very far. According to Ducomet's observations, even when the tubers are in a deliquescent state, the starch is still undecomposed, and only at a later stage does it undergo liquefaction. It is therefore advisable to collect all potatoes attacked by damp rot, whether caused by frost, or mildew or other organisms, and extract the starch, which after proper sterilization is fit for consumption by man or animals. The period during which spoiled potatoes can be kept before treatment may be considerably prolonged by covering them with water and changing this from time to time. It is pointed out by Girard that about 75 per cent of the nitrogen and 90 per cent of the potash contained in the tubers is carried off in the water in which they are washed. On the farm this water might be absorbed by manure heaps or even by the soil, to utilize the valuable constituents. If it is first brought to the boiling point, about half of the contained nitrogen is precipitated as protein, which after deposition could be fed directly to stock.—*Note in J. Soc. Chem. Ind. on an article by Ducomet A. C. Girard in Bull. Agric. Intell.*

The Use and Abuse of Steel

The authors point out that steels of widely different compositions can be made to give the same mechanical tests by different heat-treatments, and, further, that widely different mechanical properties can be bestowed on the same steel by the same means. Resistance to abrasive wear is an important factor in the choice of steel by composition. Experience has shown that a relatively high-nickel steel does not resist abrasion so well as a low-nickel steel containing a small amount of chromium. High-chromium steels are objectionable on account of their tendency toward cracking. Longitudinal "hair cracks" have been shown to form starting-points for circumferential fractures. The authors consider that in addition to the usual clauses contained in steel specifications there should be a clause dealing with the size of ingot for the particular purpose for which the specification was drawn up. The direction of "flow lines" in stampings and forgings is a very important factor. Closer coordination between designer, steel-maker, stamper, and the manufacturer of finished machined components is desirable.—*Note in Sci. Absts. on an paper by R. K. Bagnall, and E. W. Birch before the Inst. of Auto. Engrs.*

The Low Temperature Carbonization of Coal*

A Review of Its History, Theory and Practice

By Edgar C. Evans, B.Sc., F.I.C.

The question of the low temperature carbonization of coal is not a new one; the disadvantages of bituminous coal as a fuel have been recognized from very early times, and as far back as 1656 Evelyn described in his diary a "project by Sir John Winter of charring seacoale, to burn out the sulphure and render it sweete." The resulting "cinders" made a "cleare pleasant chamber fire, depriv'd of their sulphure and arsenic malignity."

In 1681 a patent was taken out by Becker and Serle for the production of pitch, tar and smokeless fuel from coal, while the Earl of Dundonald took out in 1781 a patent for making pitch, tar, oils, cinders, etc., from coal.

The early literature of the gas industry, from 1792 onwards, teems with references to low temperature carbonization, but the gas engineer's desire for the utmost yield of gas from his coal led to the adoption of higher and still higher temperatures, until to-day the highest possible temperatures compatible with the nature of the retort are universally used in this industry.

From the point of view of the gas industry, with gas as the primary product, this choice has been thoroughly justified by the results obtained and the same thing can be said of the coking industry, where a hard metallurgical coke is the main desideratum.

Neither gas coke nor metallurgical coke, however, is an ideal substance for use as a domestic fuel, and in the modern sense of the term, the idea of low temperature carbonization is the outcome of attempts that have been made to produce a smokeless fuel from bituminous coal.

In this sense, low temperature carbonization can be said to date from 1890, when the late Col. Scott Moncrieff suggested the withdrawal of the charge from gas retorts when half the usual quantity of gas had been evolved, with the idea of using it as a domestic fuel. It was found, however, that the only result was the production of a partially coked layer on the outside of the charge with an inner core of practically raw coal.

A more feasible suggestion was made in the same year by Parker, who proposed (Eng. Pat. 67, 1890) to produce a smokeless fuel by passing steam, water gas, or coal gas, superheated to a temperature of 600° to 650° C., through a mass of coal in a retort. The idea of using an inert gas as a heating medium is an excellent one, but it failed in this as in subsequent attempts owing to the peculiar nature of the phenomena connected with the carbonization of coal at these comparatively low temperatures.

In 1906, Parker took out his famous master patent (Eng. Pat. 14,365, 1906) for the production of "Coalite" by heating coal in the presence of steam to a temperature not exceeding 800° F. A number of retorts were tried, details of which are given in a series of patents taken out between 1906 and 1911. The first proposal was to use ⌂ shaped retorts about 5 ft. wide, 7 ft. long, and 16 in. high, the coal being placed in a layer not more than 6 in. thick.

Coal which melted under heat was treated in tapering cylinders about 10—12 in. in diameter, one end being perforated to allow the escape of the gases produced, or it was heated in completely filled tubes of not more than 6 in. in diameter.

These experiments failed, however, and the next step was to use a narrow vertical retort of oblong cross section, which again was replaced by bunches of vertical tubes, each tube being from 4 to 6 in. in diameter, and each separate battery of tubes being connected by means of a separate pipe with the hydraulic main. In the later patent, these tubes were provided with slots by means of which communication was established between adjacent tubes, so that if one of the tubes became temporarily choked, the gas evolved could pass up the other.

This gradual alteration in the design furnishes an interesting commentary upon the difficulties experienced by the Coalite company, and these proved so great, that despite the assistance of some of the best scientific brains of the country, and the expenditure of large sums of money, the process failed to satisfy commercial requirements.

The Coalite failure, however, served one good purpose—it created a popular interest in coal carbonization, it showed the need that existed for a free-burning smokeless fuel, and cleared up many obscure points in coal carbonization.

A considerable amount of work has since been performed on low temperature carbonization, both from a scientific and a technical standpoint, and whilst commercial success has yet to be realized, a number of the problems involved have proved capable of solution on a semi-commercial scale.

The question of commercial success by any system capable of general application is not an easy one. The process of coal carbonization itself is a most complicated one, and it is rendered still more complex by the wide differences that exist between different coals.

CONSTITUTION OF COAL

The whole phenomena of coal carbonization at low temperatures are intimately bound up with the constitution of the coal that is treated, and, in the solution of the problem, the most important requirement is a clear understanding of the nature of the coal itself. Unfortunately this is extremely difficult to obtain by purely chemical methods. The brilliant researches of Wheeler and his collaborators have established the fact that coal contains two classes of substances, *viz.*:—Resinous substances derived from the resins and gums of the vegetation from which the coal was originally formed, and cellulosic or "humic" compounds derived from the cellulose of the original vegetation. Some of the conclusions of Wheeler and his co-workers are still the subject of debate, but the following distinctive properties of these two classes of substances are agreed to by most of the workers in this field.

Cellulosic or "humic" compounds:—(1) Are infusible. (2) Yield very small quantities of liquid distillates on being heated, these consisting chiefly of phenolic compounds. (3) Are insoluble in chloroform.

Resinous substances:—(1) Have a low melting point. (2) Yield a large proportion of liquid products on distillation, these consisting below 500° C. chiefly of paraffins, naphthenes, and members of the olefine series. (3) Are soluble in chloroform, phenol, pyridine, and certain other solvents. (4) Leave on heating to 500°, a pitch which acts as a binding constituent in the formation of coke.

At first sight, it might seem possible to consider all coals as being made up of varying proportions of resinous and cellulosic or humic material, and that the properties of any coal would depend essentially on the relative proportions of these two substances that it contains. Such a constitution would, however, by no means account for the differences found in different coals. In the first place, neither resins nor cellulose contain sulphur and nitrogen, and the organic sulphur and nitrogen compounds of coal would still require a place in the essential constituents of the coal. Secondly the properties of non-coking cannels and spore coals could not be reconciled very easily with a constitution based only on resinous and humic substances.

It is therefore essential to widen our ideas of the constitution of coal to include substances other than these two, or else to broaden the terms to include substances widely differing both in constitution and in properties. Unfortunately, purely chemical methods have exhibited very serious limitations in the examination of the exceedingly complex mixture of substances contained in coal, and a clearer conception of the rational constitution of coal can probably be gained much more easily by a combination of chemical and microscopical methods.

The pioneer work of Lomax, followed by the researches of Stopes, Hickling, and others in this country, of Renault and Bertrand in France, and of White, Jeffreys and Thiessen in America have thrown considerable light on the constitution of coal. It is impossible to go into their researches in detail, but essentially, in the light of the microscopic examination of coal sections, coal can be regarded as being made up of varying proportions of humic matter, resinous substances, and cuticular substances, the last-named embracing spores, spore cases, etc. (including probably the so-called algæ noted by Bertrand and Renault in cannels), and the resistant cuticles of the original vegetation. To these can probably be added the nitrogenous and organo-sulphur compounds in the coal which presumably would have been derived from the cell contents of the parent vegetation.

It is impossible in this paper to discuss the latter substances in detail, but, from the point of view of carbonization it is of considerable importance to gain an idea of the nature of the cuticular material in coal. At first sight, it would seem probable that this would be resinous in character; under the microscope it appears as a bright yellow substance resembling very closely the resinous particles in the coal, but so far as the author is aware, the small amount of work that has been performed in this direction seems to indicate that cuticular matter in general is non-resinous in character, or at any rate, if it is resinous, it differs in many important respects from the customary resinous constituents.

In an unpublished paper read by Lomax before the Manchester Geological Society in 1914, it was shown that spore coals were non-coking in character, and this was confirmed by Lomax and the author in an examination of the Lantern Seam of the South Rhondda Colliery. This seam is highly resinous in its general character; when distilled at temperatures of 500° to 550° C., it swelled, fused, and gave a considerable proportion of liquid distillates that were not phenolic in character. When the seam was examined in detail, however, it was found that those portions which were made up of spore coals were non-expanding, non-fusible, and, except in places where resins were clearly evident, non-coking in the customary sense of the term. It appears likely therefore that the cuticular ingredients of coal are non-resinous. On the other hand, they have properties that are different from the purely humic constituents. Spore coals, even though they are non-coking, yield a large proportion of paraffin compounds on distillation at low temperatures, and this fact, together with their resistance to decay, seems to indicate a non-cellulosic origin.

Unfortunately, very little detailed work has been done as far as the investigation of the cuticular portions of living plants is concerned, but apparently they consist of cellulose combined with fatty and waxy compounds of very high molecular weight. Such a composition would account for the properties possessed by spore coals, but the exact nature of the residual product as it exists in coal has yet to be determined.

THEORY OF THE COKING PROCESS

As far as the coking property of coal is concerned, the predominant factor is undoubtedly the proportion and character of the resinous constituents that it contains. Parr and Olin (Bulletin 60, University of Illinois) as the result of a study of the low temperature distillation of Illinois coals, put forward the following hypothetical conditions as being necessary for the formation of coke:—(1) There must be present certain substances which have a definite melting point; (2) the temperature of decomposition of these substances must be above the melting point; (3) when the compounds that satisfy the first and second conditions are unsaturated, it is possible by subjecting them to oxidation so to lower the temperature of decomposition that the second condition is no longer fulfilled, in which case coking will not occur. These hypotheses seem to agree very well with the known data concerning the coking process, and, while the phenomena involved are exceedingly complicated, a fair idea can be obtained with their aid of the reactions that take place within the coking chamber.

It is necessary at the outset to distinguish between high and low temperature carbonization. In the former case, not only is the reaction complicated by secondary reactions taking place between the liquid and gaseous products at temperatures above 700° C., but there is a considerable physical difference in the structure of the resulting coke product. The secondary reactions of the liquid and gaseous products have already been very ably dealt with, and it is therefore advisable in these notes to consider only those factors that are involved in the production of coke.

As far as coke formation is concerned, the use of a high temperature simplifies the process considerably and actually reduces the number of factors that have to be considered in large scale operations.

When a charge of bituminous small coal is introduced into a coking chamber the walls of which are maintained at a temperature of say 1000° C., the outer layers become rapidly heated until, at a temperature of 300° to 400° C., they soften owing to the fusion of the resinous substances. The temperature rises too

*From the *Journal of the Society of Chemical Industry*.

rapidly for this condition to last very long, however, and gas begins to be evolved, the evolution increasing rapidly as the temperature rises, until finally the portions nearest the wall solidify. Gas still continues to be evolved from the solidified portion, and continues in fact until the coke reaches the temperature of the walls, and even then, at 1000° C., there is still left a small quantity of volatile matter which could only be expelled by raising the temperature considerably.

Meanwhile the adjacent layers towards the centre of the oven have attained the pasty stage, and gas begins to be evolved which passes principally through the porous, solid, outer layers to the wall of the oven. (*Cf.* Lewes, "Carbonization of coal," Young, J. Gas Lighting, 1912, 119, and Evans, J. Gas Lighting, 1913, 587.) A small amount possibly given off from the inner portion of the pasty mass, may pass upwards through the central core of raw coal, but this quantity would not be very great. As the gases pass through the outer solid coke, the hydrocarbons are decomposed to a certain extent with the formation of carbon which is deposited on the outer layers, thus forming a stronger, harder coke.

Essentially the coking process resolves itself into the formation of a pasty zone, which, fairly rapidly at first, but afterwards with continually decreasing speed, travels towards the centre of the oven. The rate of advance of the zone depends on the temperature of the oven walls and the thickness of the charge. The higher the temperature, the more rapidly does the fused zone pass towards the centre of the oven. In the later stages of the carbonization the rate of progress becomes very slow. It has been shown by Simmersbach, that in a coke-oven 20 in. wide, the centre of the charge remained at a temperature of 10° C. for 2 hours after charging, then rose to 100° and remained there for 13 hours, while even after 20 hours the temperature was only 410° C. (cf. Ramsburg and Speer, J. Franklin Inst., Apr., 1917).

As the coking process continues, the coke becomes fissured along lines perpendicular to the walls of the oven, and finally when the fused zones reach the centre of the oven, the resistance of the outer layers becomes greater than the resistance towards the centre of the charge, and a considerable proportion of the gas evolved passes up the centre of the charge, the coke dividing into two distinct masses.

LOW TEMPERATURE CARBONIZATION

In its main essentials, the process of low temperature carbonization proceeds along similar lines to the above, but several of the factors involved are so intensified that a radical alteration in the design of the oven is necessary for the process to be carried out on anything like a commercial scale. The following notes summarize the main differences:

(1) The low temperature (450°—550° C.) of the walls of the oven reduces enormously the rate of transmission of heat through the charge, or in other words, it reduces the velocity of the zone of fusion. For this reason, a thickness of four to five inches is the maximum that can be treated in stationary charges within economical limits of time. This factor brings in its train the following results:—(*a*) The capital outlay is increased owing to the increase in the number of units, (*b*) labor charges are necessarily increased, (*c*) the space taken up by the plant is increased, and (*d*) the maintenance cost is increased.

(2) The resistance of the fused zone to the passage of gas is enormously increased as the temperature diminishes. It has been estimated by O. B. Evans (J. Gas Lighting, 1913, 587) that the resistance offered to the passage of gas at 540° C. is about 7 times greater than at 700° C. Owing to this extremely high resistance, if for any reason the outer zone becomes choked, the gas accumulates in the charge to such an extent that serious gas pressures are developed. In several cases the author has found that when dealing with resinous coals, the gas escapes from the central portion of the charge not in a direction at right angles to the containing walls, but parallel to them, so that the resulting coke appears as if it were built up of extremely thin layers. This seems to indicate that in low temperature carbonization, the outer layers are much more resistant to the passage of gas than is the case in high temperature carbonization.

(3) The time during which the coal is in a state of semi-fusion is considerably prolonged.

In the case of high temperature carbonization the time-temperature gradient is rather steep, and the interval of time during which the coal is in a state of fusion is comparatively short. In the case of low temperature carbonization, however, this period is considerably prolonged and owing to this prolongation of the pasty stage, with the high pressures that are induced in the coal mass, the cell cavities in low temperature coke are considerably larger than is the case with high temperature coke. This produces ultimately a considerable expansion in the coke, an expansion often great enough in the case of some resinous coals and with well filled retorts to choke up the gas outlet completely. With such coals a considerable space must be left in the retorts to allow room for expansion, and the economic efficiency of the process is thus seriously affected. Further, the coke becomes porous and friable.

(4) Any free space left at the top of the coal charge increases the amount of air that is left in contact with the coal. This exerts a most deleterious action when the coal is carbonized at low temperatures and results in the formation of a friable, powdery coke.

It is evident that the low temperature carbonization of bituminous (coking) coal involves the solution of a number of problems many of which are of a most conflicting character. The records of the Patent Office contain a number of attempts to solve these problems and of these, three main classes can be distinguished, *viz*:—

(1) The use of externally heated, intermittently charged retorts.

(2) The use of intermittently charged retorts, internally heated.

(3) Continuous processes in which the coal charge is carried forward by automatic means through a retort which may be heated either externally or internally, or by a combination of both methods.

Externally heated retorts. The various types of "Coalite" retorts are on the whole typical examples of low temperature retorts. Their failure was due to the lack of detailed knowledge regarding the constitution of coal, and also to the difficulty of adapting the sysem for carbonization on a commercial scale. The Coalite trials proved one thing very clearly, however, and that was the necessity of carbonizing the coal in layers as thin as was compatible with commercial requirements. This result is achieved in a very simple manner by the Tozer retort of the Tarless Fuel Company. In this retort, the coal is charged in concentric layers, so arranged that no layer is more than 4—5 in. thick. It is obvious that much larger charges can be got into the same space than in the coalite process, the coal can be charged much more rapidly, labor charges for handling are reduced, and the heating of the retorts can be made very uniform.

The retorts are used in conjunction with Simpson's process for heating coal under a vacuum of from 20 to 26 in. of mercury. The use of such a high degree of exhaustion has certain obvious advantages. The oxygen left in the retort after charging is reduced to a minimum, the liquid and gaseous products would be removed very rapidly from the retort and possibly distillation would be effected more readily. The influence of the vacuum on the quality of the coke produced is not clear. Porter and Taylor state (Tech. Paper 140, U. S. Bureau of Mines) that Pittsburgh bituminous coal yielded a light, inferior, porous coke when slowly heated at atmospheric pressure, but at a pressure of less than 30 mm. it produced a dense coke. The reason for this is not very clear, but apparently the use of a vacuum produced a decrease in the tenacity of the tar film.

On the whole a vacuum process offers certain advantages over those carried on at atmospheric pressure; but on the other hand, from a commercial standpoint it has certain disadvantages which are obvious to workers familiar with coal carbonization on a large scale. These can be summarized thus:—(1) Increased capital outlay; (2) increased power consumption; (3) difficulty of avoiding leakage (this would be a difficult matter under works conditions, especially when working on a big scale with unskilled labor in a colliery district liable to subsidence).

Taking the Tarless Fuel process as a whole, it is attractive in many respects, but it has yet to prove its capacity for satisfying commercial requirements on a big scale.

A process that has attracted considerable attention is that carried on by the Barnsley Smokeless Fuel Company. This differs in many essential aspects from customary low temperature practice, and it might perhaps be briefly dealt with. In the first place the Barnsley retorts are made of fireclay instead of cast iron, the usual material used in low temperature retorts. Cast iron is certainly not an ideal material; its disadvantages were early recognized by the gas industry and led to its substitution by clay retorts. In the Barnsley plant vertical retorts of rectangular cross section are used which are somewhat wider than those used in most low temperature processes. In these (Eng. Pat. 108,200) four varying zones of heat were maintained, the lowest being at a temperature of about 450° C., the next 500°, the next 550°, etc., whilst finally, in the free space at the top of the charge, a temperature of 900° to 1200° C. was maintained. In this space was suspended a grid made of some suitable material (metal, metal oxide, fireclay, or carbon) so that the gaseous compounds of distillation were subjected over as great an area of contact as possible to the temperature necessary to convert the paraffinoid tars to aromatic hydrocarbons.

The author has had no experience of this plant, but from purely theoretical considerations the chances of success would be small if the above temperatures were adhered to. In the first place, the retorts are wider at the bottom, so that the zones maintained at the lowest temperatures are actually wider than those at higher temperatures. Thus the top portions would be carbonized such sooner than the lower portions, so that assuming that the lower layers could be carbonized in economic limits of time (which is doubtful) the result would be the formation of a mass of coke of very uneven quality, the lower layers spongy and porous, whilst the top layers would probably be difficult to burn. It is also difficult to see how the dangers of a serious accumulation of gas could be avoided in the lower portions, and the conditions in this respect would probably be worse even than in the "Coalite" retorts. However, the author has had no experience of the process and it would be interesting to learn something of the results that have been obtained.

A number of other examples of low temperature retorts could be given, but, taking them as a type, they possess the following disadvantages, arising mainly from the necessity of having to work with charges of coal that are neither too wide nor too high. The number of units must be considerably greater than is the case in high temperature practice, and this involves increased capital outlay, increased labor charges, increased repair costs, and a lowering of the general economic efficiency of the plant.

Internally heated retorts. In this type the coal charge is heated by the actual passage through it of inert gas preheated to a temperature sufficiently high to carbonize the charge. On purely theoretical grounds, this proposal is extremely attractive. The bulk of the time occupied in present systems of carbonization is taken up in heating the innermost layers of the coal, and if these could be heated from the outset considerable economies in time could be effected. A considerable number of attempts have been made to carbonize coal by passing through it a current of inert gas heated to a temperature of from 400° to 600° C., and Parr and Olin (Bull. 60, Univ. of Illinois) had some excellent results on a small scale by this method.

As far back as 1890, Parker (Eng. Pat. 67, 1890) proposed to pass steam water-gas or some other suitable gas superheated to 500°—600° C., with a view to making smokeless fuel, and a number of other inventors have followed along similar lines. In the case of bituminous (resinous) coals, the old difficulty arises that when the coal reaches the pasty stage it becomes impervious to the passage of the gas, but there seems to be no reason why the method should not be used for shales, cannels, or for coals that are not fusible.

The results obtained by McLaurin with a process of this type (this J., 1917, 620) are extremely interesting. As would be expected, cannel coal proved to be quite easy to work when carbonized by means of a stream of hot producer gas, but it was also found that Cadder coking coal if screened came out of the retort in the same shape and same size as it was put in. McLaurin suggests that this is due to the slow heating to which the coal was subjected and that under those conditions it did not intumesce. If this condition is applicable to all coals, it opens up possibilities of an extremely interesting character. The author, however, has not found it possible to repeat this result with the highly resinous coals of South Wales, except under conditions in which oxygen was present in the heating gaseous medium. The effect of oxygen when coal is carbonized at low temperatures has already been discussed, and the author is inclined to believe that the small quantity of oxygen which would be present in the hot producer gas in McLaurin's experiments played as important a part as the slow heating. A typical analysis of the producer gas gave 0.9% of oxygen, so that there seems to be every reason for believing that the coal was carbonized in an atmosphere containing a small proportion of this gas, an idea which is confirmed by a study of the properties of the tars obtained.

Another proposal of this type is that given by Lamplough (Eng. Pat. 108,343, 1917), the heating medium in this case being steam.

On the whole, internal heating seems to offer con-

siderable possibilities in the treatment of shales, cannels, and possibly certain types of coal if carefully screened, but as McLaurin and others have found, difficulties would arise in the carbonization of fine coal in this way. There is perhaps one point that would need consideration, and that is, if a small proportion of oxygen were systematically introduced into the heating gas, what would be the effect upon the tars produced? These apparently would have a similar composition to the old Jameson tars, which were produced under conditions theoretically analogous to those existing in McLaurin's process.

Continuous processes. The third class of retort which has been proposed for the low temperature carbonization of coal is that in which the coal is carried forward through the furnace by means of a conveying system.

The Archimedean screw has been suggested as a suitable carrier for quite a long time. A most interesting anticipation of one of the most modern of these systems is given in Patison's Eng. Pat. 569, 1873, in which coal, shale, or other fuel is carried through a heated retort by means of a worm conveyor. For low temperatures—with a high oil yield—the inventor proposed to use a cast iron retort, but for high temperatures he suggested the use of a fireclay furnace.

The well-known Del Monte system differs only slightly from this system, but it had one innovation, and that was in the use of a screw mounted on a hollow shaft, which was heated internally by a row of jets from a central gas pipe. Further, the coal was subjected to a fractional distillation, one end of the retort being maintained at a considerably lower temperature than the other. This retort again could be used for wood, shale, lignite, or peat, but with coking coals, the swollen pasty mass which was produced completely prevented the working of the screw.

It seems difficult to believe that any system which involves the stirring up of the coal in any way can be used for bituminous coals, and for that reason, it is doubtful whether a continuous system on the lines of the Woodhall-Duckham or the Glover-West retorts can be used for the low temperature carbonization of these coals, except perhaps under conditions already touched upon.

On the other hand, there seems to be no reason—apart from those connected with engineering difficulties—why the coal should not be conveyed through a furnace by some system in which the coal itself is not stirred.

A system of this type that has been worked with some degree of success is that introduced by Pringle and Richards. In this the coal is carried by means of an endless conveyor through a retort the temperature of which is maintained at about 500° C. The conveyor itself is fitted with compartments so as to subdivide the coal into a number of separate small charges each of which is rapidly heated to the desired temperature. The coal itself is undisturbed in its passage through the retort, and leaves as a porous semi-coke which is an excellent domestic fuel. This process as yet has only been worked on an experimental scale; the obvious difficulties are of an engineering character and whether or not they can be overcome on a large scale plant remains to be proved.

A system of this type seems to offer several advantages for low temperature carbonization; temperature control could be readily effected, labor charges would be low, and by suitable engineering methods the rather heavy capital outlay and high maintenance and repair costs which would probably be inherent in this particular system could be reduced to a limit which would make it a commercial proposition.

A number of other proposals could be given, but as yet, not one of them has been tested on a commercial scale. As far as the author can see there does not seem to be any overwhelming difficulties in the way of the low temperature carbonization of shales, lignites, cannels, etc., whilst for resinous coals, success will probably be attained only by an individual study of the coals it is desired to treat, accompanied possibly by a suitable preliminary treatment which will give a final product of sufficient solidity and strength to withstand customary conditions of handling and transport. In this connection the briqueting of the coal either before or after carbonization will have to receive very serious consideration. The main considerations in this direction are economic in character and in the present artificial conditions prevailing in the coal market it would be extremely difficult to estimate the commercial possibilities of such a combination.

Economics of low temperature carbonization. An attempt might, however, be made to review from a general standpoint the financial possibilities of low temperature carbonization, and this perhaps is all the more necessary because of the extravagant estimates that are periodically issued from certain sections of the financial press. In this connection it must not be overlooked that there are many coals which are almost unusable in the raw state, and in some cases even there are whole coalfields in which the coal is of such quality that under the economic and geographical conditions prevailing in their immediate vicinity they are commercially unworkable. Several such cases have been brought to the author's notice in which a well designed system of low temperature carbonization would result in the economic salvation of the coalfield. Disregarding for the present these exceptional cases, there remain two or perhaps three main directions in which the adoption of low temperature carbonization has been strenuously advocated.

The first is in the treatment of cannel coal. From a technical standpoint this does not appear to present any very serious difficulties, and the question practically resolves itself into a commercial one. The matter has already been fully treated recently ("A New British Oil Industry," Craig, Perkin, Berry, and Dunstan, J. Inst. Petrol. Tech., Apr., 1918) and need not be discussed here. In this case, however, the utilization of the residue is the factor upon which the success or failure commercially depends. The method usually suggested is to gasify the residue in producers of the Mond type and recover the ammonia produced (see Paton, Iron and Coal Trades Review, Mar. 22, 1918, and "Fuel Economy," paper read before Birmingham Section, Inst. Elect. Eng., 1917). Technically such a process would be ideal, especially if the carbonization and gasification could be performed in one plant as proposed by McLaurin (this J., 1917, 620) or Wolloston (Eng. Pat. 111,964, 1918); there is one point which needs to be emphasized, the necessity for considering the Haber process as a factor in the reduction of price of ammonium sulphate after the war. It is estimated by the Barrett Company of New York, that the production of ammonia from this process alone amounted in 1917 in Germany to a quantity equivalent to over 1,000,000 tons per annum of ammonium sulphate. The world demand for this fertilizer is increasing rapidly, and there is every prospect of a still further increase during the next few years, but with a competitor of this magnitude in the field, there is every need for caution in considering the claims of the recovery producer against the cheaper and technically more efficient non-recovery producer.

There is one other point that can be only briefly dealt with, and that is the relation of the gas industry to low temperature carbonization. In the author's opinion, the gas engineer, to whom gas is the main and primary product, is quite justified in adhering to high temperatures in general practice. The yield of gas in low temperature carbonization is far too low to make it attractive to the gas engineer, and with humic coals this small quantity is seriously contaminated with carbon dioxide. Further, to attain a total yield comparable with present practice, the capital outlay would be considerably increased, the space required for the plant would be very much greater than in present practice, and the labor costs (per 1000 cub. ft. of gas) would be enormously increased.

There are of course advantages in favor of low temperature practice, but in view of the standardized conditions prevailing in the gas industry, with works already cramped for space in many cases, and with heavy capital charges on plant already installed, it is extremely difficult to see where its advantages come in. Gas coke is certainly not an ideal product either from a domestic or an industrial standpoint, but by suitable preliminary treatment of the coal used, even this can be made an excellent free-burning product; and if the market conditions allow, the gas engineer can always erect additional plant for this purpose. Apart entirely from any preliminary treatment, however, the uses of gas coke are rapidly extending and before long it should cease to be the drug on the market that it has been in the past.

Taking everything into consideration, the gas engineer is well advised in rejecting low temperature carbonization as being unsuitable for the purpose of producing gas in as great a quantity and of as high a quality as possible.

High-Speed Steel for Milling Cutters, Taps and Reamers

WHILE tungsten high-speed steel has been used for some years for probably nine-tenths of all turning, planing, and slotting tools, it has been employed for a much smaller percentage of milling cutters, taps, reamers, etc. This small use is partly due to the difficulty of hardening tools with fine edges, for to obtain the best efficiency, tungsten high-speed steel requires hardening at from 1,250 to 1,350 degrees C. As the manufacture of munitions calls for the most efficient tools of all kinds, experiments were made by Darwin & Milner, of Sheffield, England, to find a steel that, without tungsten, would possess the hardness of the so-called high-speed steels. As a result, it was discovered that the addition of cobalt to chromium-carbon steel produces a most satisfactory tool with a hardening temperature of only 1,200 degrees C.; in fact, if this is exceeded, the tools give poorer results. Hardening for practically all applications is said to be satisfactory when the tool is allowed to cool naturally in still air, free from drafts. This new alloy, known as "cobalt-crom," has been found especially suitable for milling cutters, twist drills, reamers, taps, and forming tools, and for machining gun-metal and yellow metals, as well as for high-endurance drawing and blanking dies, lathe centers, shear blades, airplane and automobile engine valves, and all gages and instruments that must resist abrasion. In one test, it was possible to cut for a half day with carbon-steel saws without regrinding; for two days with tungsten high-speed steel saws; and for four days with cobalt-crom saws.—*Machinery*

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Table of Contents